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THOUGHTS ON THE FUTURE OF THORACIC SURGERY IN AMERICA*

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IN 1924, when attending the seventh annual meeting of the American Association for Thoracic Surgery at Rochester, Minn., I was asked at a dinner, given to the fellows and guests, to speak on "The Future of Thoracic Surgery." On that occasion I was absolutely unprepared. So I just said a few words as they happened to come to my mind at the moment. Since then I have given this question frequent and serious thought, and would now ask your indulgence for a few remarks on the subject.

Affections of the thoracic viscera—if we exclude for the moment empyema and tuberculosis of the lungs—are much rarer than those of the abdominal region, intra- and retro-peritoneal. The most frequent thoracic lesions encountered nowadays are those due to an acute traumatism resulting from automobile accidents, such as occur daily on our streets and country roads. The medical profession and the public still call them briefly "severe internal injuries." Other frequent causes are accidents in factories, shot or stabwounds and so forth. Up to this day many of these cases die without even an attempt being made to bring help, owing to the inability of the average medical man, on account of lack of proper training, to render a strict or preliminary diagnosis. Yet, what a large percentage of those thus afflicted could be saved, if even the mere principles of thoracic surgery and the necessary prompt surgical procedures, conservative and radical, were taught at college and were more generally practised.

The correct use of a trocar, and airtight connection of the rubber tube introduced into the chest through its canula with a syphon bottle under the operating table and later on under the bed of the patient, would in many such cases avert the immediate dangers of an increasing pressure pneumothorax, as it is so frequently observed in this class of accidents. If at a smaller hospital in the country the attending surgeon cannot be reached at once, this simple procedure at the hands of the house surgeon may bridge over anxious hours or even bring permanent help. After the arrival of the older doctor and further careful observation, an intercostal incision would promptly determine whether there is an internal hemorrhage above the dia-

* Read before the American Surgical Association, May 12, 1927.

phragm, and in that event the ligation of the bleeding vessels or the closing of a possible rent in the lung or bronchus would often save the patient's life.

If such work were done by the average surgeon, it would become an accepted fact that operating within the thorax is no more dangerous than operating in any other part of the body, the only additional care to be exercised being that of guarding against the danger of the onset of the acute pneumothorax.

The only variation, or, let us say, addition in the light of the most modern developments is, that it will be necessary for the anæsthetist to master the use of the Gwathmey apparatus—or any other kind of anæsthetizing apparatus embodying Tiegel's principle †—and of the tightly fitting mask, in order to administer the required anæsthetic, gas-oxygen, with or without ethylene, or any other mixture of an anæsthetic with oxygen, under sufficient pressure to avoid the otherwise threatening complete collapse of the lung, which, as is well known, adversely influences the work of the other lung by the flopping of the mediastinum. Tiegel, as early as 1908, demonstrated to the profession that one millimetre plus-pressure of oxygen suffices to rule out the accumulation of carbonic acid gas within the blood, which in the last analysis is the real cause of the patient's eventual death if an acute pneumothorax has not been properly guarded against.

To-day the negative chamber, positive pressure cabinets or boxes and intratracheal insufflation have become more or less obsolete. The pressure of the oxygen tank with the tightly fitting rebreathing bag is the only outfit required to make operative work within the thorax safe.

Do we then need men with special training for the practice of thoracic surgery alone? Certainly not, it seems to me. The men at the present time practically interested in thoracic surgery are all general surgeons who, on basis of their personal inclination and the great fascination of working within the chest, simply have added thoracic surgery to their usual daily work. Anæsthesia, asepsis, assistance, technic, all are the same as called for in operations upon other parts of the human body.

To my mind, therefore, thoracic surgery should constitute a part of the daily work of the general surgeon, at least in the small and medium-sized hospitals. Large institutions naturally require the division of the operative work, and here it may be advisable to entrust the thoracic part of the surgical work to one man, though rotation would probably be welcomed by many of the attending surgeons. It has been invariably observed that any surgeon who has once tested actual operative thoracic work will never give it up again, but will continue to practise it as a most fascinating addition to his routine work. The diaphragm should not and must not be the dividing line for the general surgeon! And inasmuch as thoracic surgery is not only the youngest child of general surgery, but also its last child, there now remaining not a nook or corner in our entire body that is still a closed book,

† Tiegel, Max: Ein einfather Apparat zur Überdrucknarkose. Centralbl. f. Chirurgie, 1908, vol. xxxv, p. 679.

the general surgeon's training should include also this branch of surgery. He should be able to reach every spot of the human organism with the knife. And this, let us add proudly, can now be done safely.

Quite naturally, in the first years or decades after a new chapter of medical science has been definitely opened, there is but a comparatively small number of men sufficiently interested to help evolve and develop the new chapter. These men do a sort of pioneering and specializing work. They are looked upon as being specially fitted to treat, and operate on, these cases, and rightly so; and they will have sent to them such cases by others. But later on, by sheer necessity, a larger proportion of the profession will become more and more interested; they will study the anatomy more carefully, will try to get the necessary training and then add the new branch of work to their daily routine. Gradually the chapter will lose the character of specialization and will become the *general property* of the profession. Particularly will the younger generation, I believe, be attracted to thoracic surgery. Thus, *e.g.*, at the Lenox Hill Hospital in New York—where the division of the operative work by regions of the body does not exist, because up to now the number of beds has not been large enough for such an arrangement—every attending, associate and adjunct surgeon is most enthusiastically interested in thoracic surgery.

This interest, I believe, will spread, and with the work in this particular field steadily increasing there will be established everywhere in this wide country, in all the medical schools of repute, clinics in thoracic surgery alongside of those already existing for other branches of surgery. In fact, I believe, that before long *all* surgical diseases of the human body will be discussed and treated in one and the same university clinic, with the exception, perhaps, of neurological and orthopædic surgery, and the specialties of eye, ear, nose and throat.

Still, it is only natural that many a surgeon will decide to practise thoracic surgery as a specialty, same as he may elect to be a specialist in the surgery of the brain, of the abdomen, the genito-urinary system, fractures, etc. However, the vast extent of our country requires the existence of men everywhere with an all-around surgical training, men that are prepared to give help in emergencies, no matter in what part of the body such help may be required; for, most of these acutely injured persons need prompt attention, they cannot and should not be obliged to travel over long distances to a large hospital, lest they die on the way.

For this and many other reasons, I think, it will soon be deemed necessary to add at least the teaching of the principles of thoracic surgery to the curriculum of the student in our medical colleges. At examinations to-day the student is required to know the anatomy and pathology of the chest. Before long, I am convinced, it will be considered wise to go a step further and teach him also how to bring help by operation, whenever such is indicated. I am sure the student will like the work, and many a young man will

decide to better round off his general surgical training by including thoracic surgery in his daily practice.

Of course, he will also add the required technic for empyema, acute and chronic, and the modern operations for pulmonary tuberculosis, which in their technic are no more specialized now than they were twenty-five years ago. He will be ready to operate, if needs be, on any of the various organs found in the chest, he will have learned from the experience of those who worked before him, and he will do his share toward the establishment of that all-essential coöperation with the internist, bacteriologist, radiologist and bronchoscopist, as is customary to-day in all those hospitals in which the attending staff can lay claim to the honor of being considered by the profession at large as "up-to-date men".

Summing up we might say:

1. Operative work within the chest is the same as in any other part of the body as far as surgical technic is concerned.

2. With the application of the customary asepsis, such work is also equally safe, if oxygen plus a volatile narcotic is added under pressure to the usual method of anæsthesia.

3. Injury of the thoracic viscera in accidents offers the most frequent indication for operation within the chest. Without prompt operation such injury often takes the patient's life in a few hours. If persons thus injured are conveyed to the nearest hospital they should there find the attending surgeons and their staff trained to bring help according to modern teachings and modern principles.

4. For these reasons it seems to be a matter of necessity that thoracic surgery, at least in its most important and vital principles, be added to the curriculum of the students in our medical colleges. Should such addition unduly crowd the already overburdened schedule of work, other less vital subjects should be dropped, the decision to be left to the judgment of committees appointed for this purpose.

5. The great fascination of this chapter of surgery will likely make such teaching a most welcome addition for the medical student as well as for the older surgeon.

6. Considering all these points, it is our belief that, in view of the favorable conditions under which thoracic surgery can now be undertaken, it will not be long before it will become as much the general property of the profession as is the surgery of the abdomen and of other parts of the body at the present time.

THE RELATION OF IMMUNITY TO THE EXPERIMENTAL PRODUCTION OF ABSCESS OF THE LUNG*

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At the meeting of this Association in Detroit one year ago we reported a method by which we could produce abscess of the lung in dogs with great constancy.† The method consisted of setting free in the jugular vein an embolus made by filling a small segment of the femoral vein with bacteria and blood. In an attempt to bring the experimental work into closer analogy with what occurs in human cases, unenclosed, infected clots were set free in the jugular vein. Such clots resulted in a wide variety of lesions but commonly in a rapidly spreading and fatal pneumonitis. It would appear that the type of lesion produced in the lung might vary either with the pathogenicity of the organism or the degree of immunity present in the animal at the time the embolus reached the lung. Last year with our presentation of the method by which abscess of the lung could be produced, we reported a single experimental study in which the immunity of the animal was varied by vaccination, previous operation, and the use of aseptic emboli.

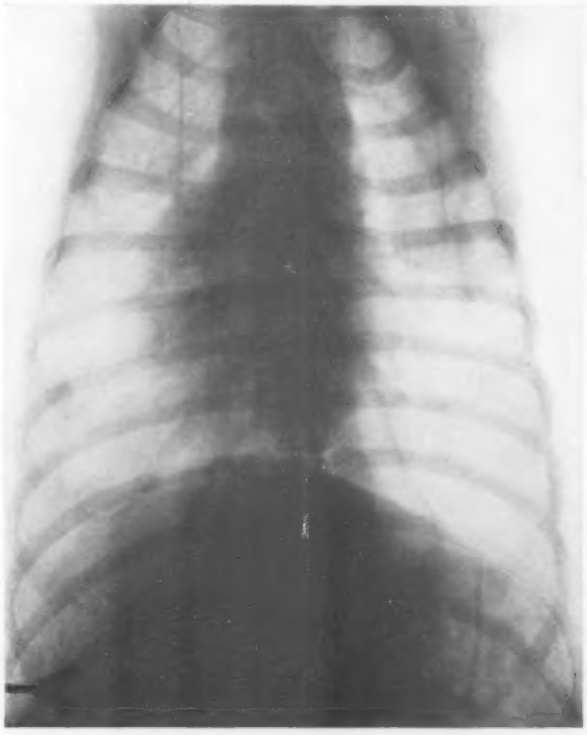

Fig. 1.—Experiment I, Dog A: There is a localized area of increased density in the right lower lobe with a suggestive area of rarefaction in the centre (five days after embolism).

* Read before the American Surgical Association, May 12, 1927.

† Cutler, E. C., and Schlueter, S. A.: The Experimental Production of Abscess of the Lung. Annals of Surgery, vol. lxxxiv, pp. 256–270, August, 1926; Tr. Am. Surg. A., vol. xliv, pp. 149–171, 1926.

These early experiments concerning the part immunity may play in the production of embolic pulmonary disease led us to a more extensive investigation of this side of the problem. It is these studies which we now wish to present. They may be grouped as I, Studies in which the general immunity of the animal is concerned, and II, Studies in which the virulence and physical properties of the infected clot are concerned.

Our first studies dealt with the problem of general immunity in which the animals' immunity was varied by vaccination previous to operation. We thought that by increasing the resistance of the animal to the specific organism which was later to be used in the embolus, there would be present conditions comparable to what occurs in man where sepsis in the operative field may increase the immunity toward the organisms which might later reach the lung in a post-operative embolus. The following experimental arrangement throws some light on this question:

Experiment I.—Four dogs were used in this experiment. Varying degrees of immunity were conferred on Dogs A, B, and C by previous intravenous injection of a vaccine made from the same organism which was later used in the infected clots. This vaccine was made from a suspension containing virulent B. coli organisms (one twenty-four-hour agar slant culture in 6 c.c. of 0.4 per cent. phenol solution). The organisms were allowed to become attenuated during a period of forty-eight hours. Dog A was given 2 c.c. of this vaccine on three successive occasions with an interval of two days between the injections; Dog B was given 2 c.c. and two days thereafter 1 c.c. of vaccine; Dog C was given 1 c.c. of vaccine. Two days subsequent to the last injections, an infected clot (3 mm. by 10 mm.) was injected into the general circulation (*via* the external jugular vein) of each of these dogs as well as into a control (non-immunized) animal, Dog D. The resulting pulmonary lesions were followed with the aid of röntgenograms.

EXPERIMENT I

Protocol Dog A (Y 69).

Black and brown mongrel, male, wt. 11.9 kg.

Immunized as previously described (3 x 2 c.c. vaccine).

5-28-26—Temp. 38.5° C. Röntgenogram shows normal pulmonary fields. Under M. S. and local anæsthesia the left external jugular vein isolated and an infected clot (3 x 10 mm.) injected into the general circulation.

5-29-26—Temp. 39.4° C. Röntgenogram same as above.

5-30-26—Temp. 38.8° C. Röntgenogram same.

5-31-26—Temp. 39.0° C. Röntgenogram same.

6- 1-26—Temp. 40.5° C. Röntgenogram shows a localized area of increased density right lower lobe.

6- 2-26—Temp. 39.5° C. Röntgenogram shows the same area of increased density right lower lobe with area of rarefaction in the centre, Fig. 1.

6- 5-26—Temp. 38.6° C. Haziness in right lower lobe diminished.

6- 9-26—Temp. 37.3° C. Röntgenogram reveals some peribronchial thickening but the peripheral pulmonary fields are clear.

The dog apparently made a complete recovery.

Protocol Dog B (Y 70).

Brown and white mongrel, male, wt. 14.8 kg.

Immunized as previously described (2 c.c. and 1 c.c. vaccine.)

5-28-26—Temp. 37.0° C. Röntgenogram shows normal pulmonary fields. Under M. S. and local anæsthesia the left external jugular vein isolated and an infected clot injected into the general circulation.

5-29-26—Temp. 39.9° C. Röntgenogram shows a triangular area of increased density (base toward the periphery) in region right lower lobe.

5-30-26—Temp. 38.7° C. Röntgenogram reveals a slight increase in the area of density noted above.

6-2-26—Temp. 38.0° C. Röntgenogram same as noted above except that there is a suggestive area of rarefaction in the centre, Fig. 2.

6- 3-26—Temp. 38.0° C. Röntgenogram shows same localized area of increased density with some suggestion of resolution. Right lower lobe removed by lobectomy. The lobe is adherent to the lateral wall of the chest, friable adhesions being broken down without difficulty. The removed lobe shows upon its surface near the outer border a wedge-shaped portion of discoloration with the base toward the periphery. There is a small abscess in the centre of this surrounded by an area of increased density.

Protocol Dog C (Y 71).

Short-haired white mongrel, female, wt. 6.9 kg.

Immunized as previously described (1 c.c. vaccine).

5-28-26—Temp. 38.2° C. Röntgenogram shows normal pulmonary fields. Under M. S. and local anæsthesia the left external jugular vein isolated and an infected clot injected into the general circulation.

5-29-26—Temp. 39.8° C. Röntgenogram same as above.

5-30-26—Temp. 39.9° C. Röntgenogram shows a well localized area of increased density in the left lower lobe with suggestive area of rarefaction in the centre.

6- 1-26—Temp. 39.0° C. Röntgenogram reveals further increase in the area of localized density in the left lower lobe. The suggestive area of rarefaction in the centre is still visible.

6- 2-26—Temp. 39.4° C. Röntgenogram shows some slight increase in the area of increased density in the left lower lobe, the central area of rarefaction appearing larger.

6- 3-26—Temp. 39.2° C. Röntgenogram suggests some resolution of the area of increased density, and it was decided to sacrifice the dog. Necropsy reveals a fairly well consolidated left lower lobe, the adjoining portion of the left upper lobe being adherent to the lower lobe with some slight infiltration. The visceral pleura overlying the left lower lobe is thickened and there appears to be some breaking down of the pulmonary tissue near the tip of the lobe. Upon sectioning the lung through this area a fairly large abscess is found near the tip of the lobe, the surrounding lung being the site of a suppurative pneumonitis, Fig. 3.

Protocol Dog D (Y 72).

Brown and white short-haired mongrel, wt. 6.9 kg.

Control animal (not immunized).

5-28-26—Temp. 38.2° C. Röntgenogram shows normal pulmonary fields. Under M. S. and local anæsthesia, the left external jugular vein isolated and an infected clot injected into the general circulation.

5-29-26—Temp. 39.7° C. Röntgenogram shows diffuse cloudiness of right lower lobe.

5-30-26—Temp. 40.3° C. Röntgenogram reveals marked increase in density right lower lobe and some increase in density in region of left lower lobe, Fig. 4.

Exitus. At necropsy cloudy hemorrhagic fluid found in both pleural cavities. Fluid cultured and pure strain B. coli obtained. Right lower lobe quite densely consolidated and left lower lobe shows scattered areas of infiltration (apparently the site of diffuse suppurative pneumonitis).

Dog A, which presumably had acquired the greatest degree of immunity, developed a small localized abscess which rapidly resolved; Dog B possessed a lesser degree of immunity, sufficient, however, to localize the lesion; Dog C had very little immunity toward the organism, and although the lesion was quite diffuse at first, it was subsequently walled off; Dog D (control, non-immunized) failed to localize the process and developed a diffuse pneumonitis which ultimately resulted in death.

In a series of four such experiments it was found that the animals in which some degree of immunity had been established by vaccination tended to wall off the reaction about the unenclosed, infected clot and to produce abscess of the lung. The control animals in such experiments usually succumbed to a diffuse pneumonitis.

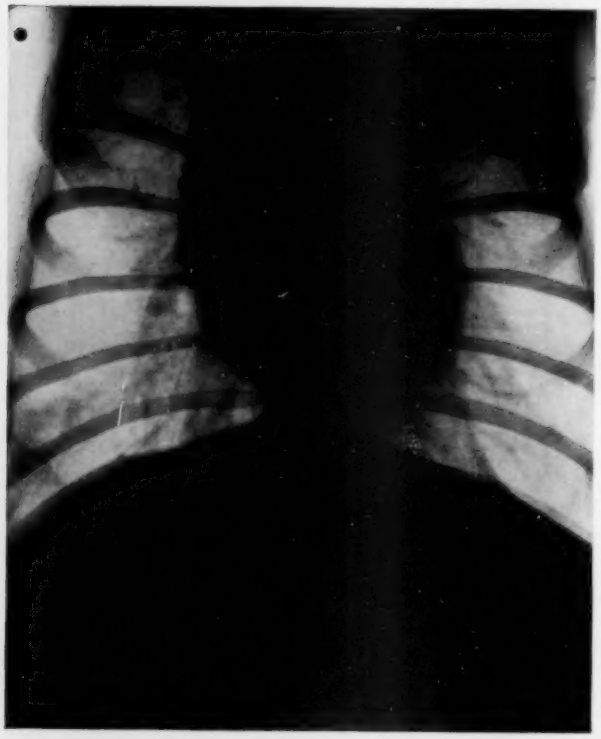

FIG. 2.—Experiment I, Dog B: There is a small area of rarefaction in the central portion of a triangular area of increased density in the right lower lobe (five days after embolism).

The foregoing experimental series, however, was not similar to what might be present in human cases in that the clot was manufactured *in vitro*. To obviate this objection a series was started designed to produce an infected intravascular clot in the living animal. To create the necessary conditions, a vein was exposed, traumatized and the tissues about it were then infected. These factors were met by the following experimental plan.

Experiment II.—The left external jugular vein was isolated and a proximal ligature placed in order to create stasis and to avoid possible premature separation of the thrombus. The wall of the vein was traumatized distal to the ligature for a distance of 2 cm. by repeated pinching of the wall of the vein with a hæmostat. The cul-de-sac distal to the ligature was allowed to fill with blood and a clamp was placed at the upper limit of the traumatized area of vein to isolate temporarily the segment of vein with its contained blood from the general circulation. Three minims of a saline suspension of B. coli (3 c.c. saline to a twenty-four-hour agar slant culture) were then introduced into the isolated segment by means of a syringe and needle and thoroughly mixed with the blood. Three minims of this mixture of blood and bacteria were then withdrawn and allowed to contaminate the surrounding tissues. The clamp was then removed and the wound closed. In the majority of cases this procedure resulted in thrombosis within twenty-four hours which could subsequently be used as a source for infected emboli. After twenty-four hours the segment of thrombosed vein was excised between clamps, the thrombus shelled out and a measured fragment injected into the general circulation

via the opposite external jugular vein by means of a syringe, cannula and 30 to 40 c.c. of saline.

The lesions obtained with this procedure were almost identical with those obtained when the unenclosed, infected clot was employed, providing the thrombus was excised and injected within twenty-four to thirty-six hours after its formation. If it was allowed to remain three, four, or five days before excision and injection, a lesion rarely resulted. This naturally suggested that with the elapse of time certain changes occur which either modify the general resistance of the animal or the character of the thrombus (consistency and virulency). In view of the fact that the experiment extends over a relatively brief period of time, the character of the thrombus is probably a more dominant factor than the question of the acquired immunity.

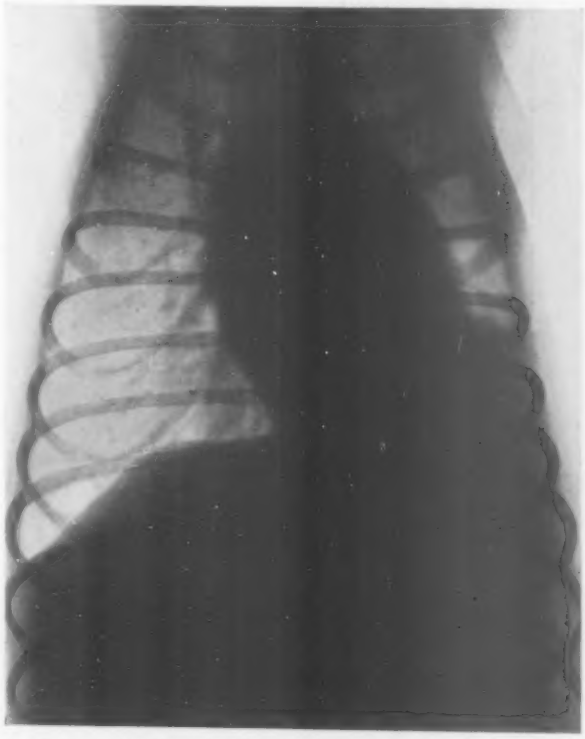

FIG. 3.—Experiment I, Dog C: There is an area of increased density in the left lower lobe with an area of rarefaction in the centre (six days after embolism).

The further factor of the variation in the character of the thrombus from which the embolus arises called forth additional experiments. In an effort to investigate the possible relation between the character of the embolus and the type of the pulmonary complication resulting therefrom, we conducted a series of experiments employing three animals in each, in which the variations in the character of the embolus were achieved by utilizing in Dog A, a segment of a twenty-four-hour thrombus excised from another animal (homologous), in Dog B, a segment of a twenty-four-hour thrombus excised from the same animal (autogenous), and in Dog C, a segment of a seventy-two-hour thrombus excised from the same animal (autogenous). The thrombosis in each case was produced in the manner previously described, the same suspension of organisms employed and the animals standardized in so far as possible. The conditions established in A were a thrombus exposed to the tissues of the body for twenty-four hours, animal not subjected to the infection; in B a thrombus exposed to the tissues of the body for twenty-four hours, animal subjected to the infection; in C a thrombus exposed to the tissues of the body for seventy-two hours, animal subjected to the infection.

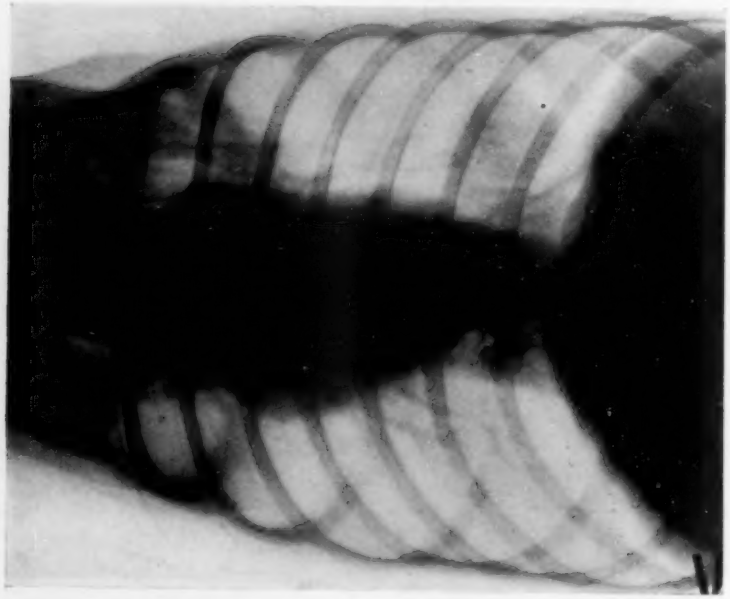

FIG. 5.—Experiment II, Dog A: There is a sharply circumscribed area of increased density in the left lower lobe (one day after embolism).

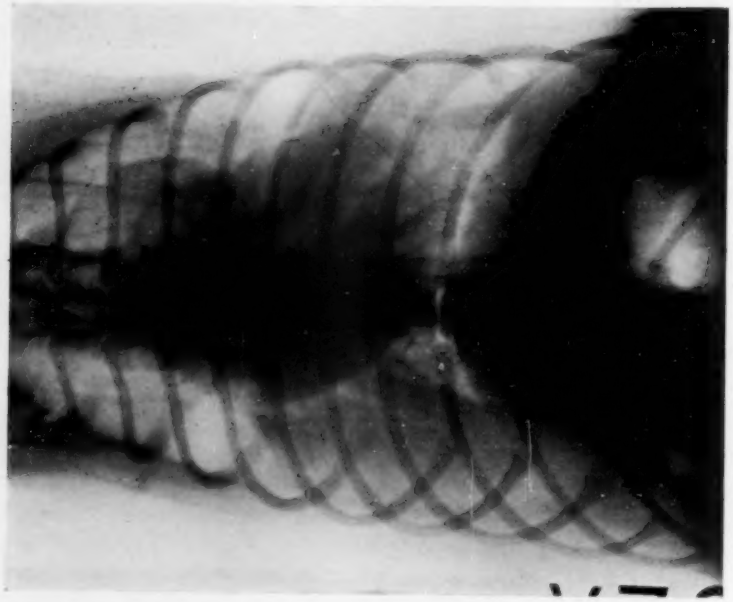

FIG. 4.—Experiment I, Dog D: There is an increase in density in the entire right lower lobe and the upper portion of the left lower lobe (two days after embolism).

EXPERIMENT II

Protocol Dog A (W 34).

Brown and white collie, male, wt. 14 kg.

3-20-27—Temp. 38.8° C. Röntgenogram reveals normal pulmonary fields. Under M. S. and general anæsthesia a segment (3 x 8 mm.) of twenty-four-hour thrombus (homologous) injected into the general circulation *via* the right external jugular vein.

3-21-27—Temp. 40.0° C. Röntgenogram shows a sharply circumscribed area of increased density in the left lower lobe, Fig. 5.

3-22-27—Exitus. Necropsy reveals a bilateral sero-purulent effusion (B. coli cultured), increased density of entire left lower lobe with an even firmer area (2 x 2 cm.) in the centre.

Protocol Dog B (W 35).

Brown collie, male, wt. 16 kg.

3-19-27—Temp. 38.6° C. Röntgenogram reveals normal pulmonary fields. Under M. S. and local anæsthesia the left external jugular vein isolated and thrombosis initiated in the usual manner.

3-20-27—Temp. 39.4° C. Röntgenogram same as above. Under M. S. and general anæsthesia the thrombus excised in the usual manner and a segment (3 x 8 mm.) of thrombus (autogenous) injected into the general circulation *via* the right external jugular vein.

3-21-27—Temp. 40.6° C. Röntgenogram shows a diffuse area of increased density right lower lobe and upper portion left lower lobe, Fig. 6.

Exitus. Necropsy reveals a bilateral sero-purulent effusion (B. coli cultured), a right lower lobe of increased density throughout, an increase in density upper portion of left lower lobe and small areas of infiltration throughout the other lobes.

Protocol Dog C (W 36).

Brown, black and white collie, male, wt. 16 kg.

3-19-27—Temp. 38.6° C. Röntgenogram shows normal pulmonary fields. Under M. S. and local anæsthesia the left external jugular vein isolated and thrombosis initiated in the routine manner.

3-21-27—Temp. 39.0° C. Röntgenogram same as above.

3-22-27—Temp. 39.2° C. Under M. S. and general anæsthesia the thrombus excised in the usual manner and a segment (3 x 8 mm.) of the thrombus (autogenous) injected into the general circulation *via* the right external jugular vein.

3-23-27—Temp. 39.0° C. Röntgenogram same as above.

3-26-27—Temp. 39.2° C. Röntgenogram same, Fig. 7.

3-28-27—Temp. 38.8° C. Röntgenogram same. Sacrificed. Necropsy, all lobes air-containing throughout, a lesion not present.

Thus far (five series), all of the C dogs have escaped any serious pulmonary lesions as revealed by röntgenograms for several days following injection and by necropsy; those surviving were sacrificed on the sixth day. As for the A and B dogs, all have developed either a diffuse pneumonitis and a sero-purulent effusion with subsequent exitus in twenty-four to forty-eight hours or a well-localized lesion (single or multilocular abscesses) which necessitated sacrifice upon the sixth day for necropsy. Inasmuch as the above types of lesions were about equally distributed in the A and B dogs, we cannot make any distinction between them; however, it is our definite impression that the B dogs have had the more severe reaction. Needless to say, further data is necessary. Nevertheless, this brings up the interesting question of a reduced or "negative phase" in the general resistance at the onset of an infection.

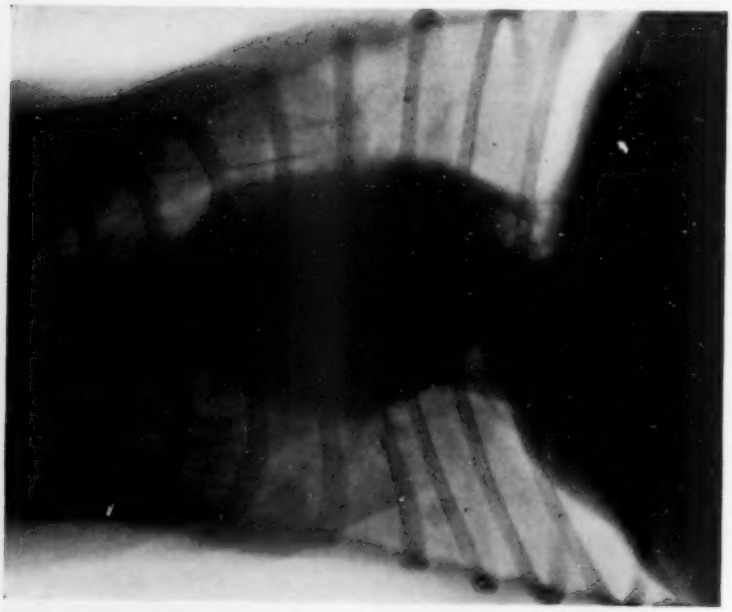

FIG. 7.—Experiment II, Dog C: There are no definite areas of increased density (four days after embolism).

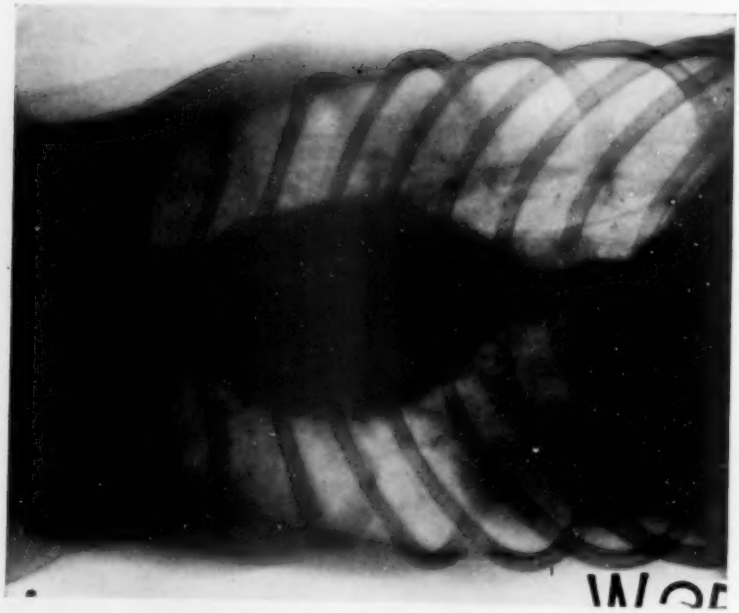

FIG. 6.—Experiment II, Dog B: There is increased density in the region of the entire right lower lobe and upper portion of the left lower lobe (one day after embolism).

The uniformity in the results obtained in the C dogs suggests that the older the thrombus from which the embolus arises, and therefore presumably the more attenuated the organisms within it, the greater the liability to a minor and less disturbing pulmonary complication. Somewhere between the two lies the question of the production of abscess of the lung. It is obvious that to produce abscess we must have on one hand organisms present of such virulence as to continue growth, and on the other the further and more intricate problem of an immunity insufficient to kill off the organisms when they reach the lung and yet sufficient to wall them off into a localized lesion.

In reviewing the question of those suppurative pulmonary complications which are embolic in origin, it would seem that there are three variables, any one of which might become a dominant factor in determining the type of lesion resulting. We elected to maintain the organism unaltered and in Experiment I, attempted to vary the resistance of the animals; in Experiment II, we sought to vary the character of the embolus. Under the conditions of our experiments, the results obtained in Experiment I, would suggest a localizing influence upon the part of a high general resistance; those obtained in Experiment II, would suggest that the older the thrombosis from which an embolus arises, the greater the likelihood that a minor and less serious pulmonary complication will result.

THE TREATMENT OF PULMONARY SUPPURATION[1]

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Pulmonary suppuration reveals itself in many forms. Obviously, therefore, no particular treatment can be applicable to all cases. Roughly speaking, we may think of acute and chronic cases, but in each group one recognizes many widely different types. For example, among the acute cases there occur such variations in pathology as a single well-defined abscess, multiple unilateral or bilateral small abscesses, a diffuse suppurative pneumonitis, etc. Again, any one of these may be associated with complications, such as a foreign body, empyema, meningitis or brain abscess, pericarditis, suppurating nasal sinuses, etc. When a pulmonary suppurative process becomes chronic it may assume the form of a chronic single large abscess, of multiple abscesses, or of bronchiectasis which is usually also associated with multiple small abscesses. It may also be accompanied by any or all of the complications mentioned above and in addition it very often is associated with a carcinoma of the lung, either primary or metastatic, or with pulmonary tuberculosis. Moreover, since pulmonary suppuration is a non-specific disease, it may be due to a great variety of microörganisms. The clinical course, prognosis and treatment will to some extent be affected by the variations in the infecting agents.

The methods of healing, however, of a suppurative process are fundamentally the same, regardless of whether it is in the lung or in any other organ of the body. Likewise, the principles of treatment of a pulmonary suppuration are essentially the same as those of any other suppuration. These are removal of foreign bodies, establishment of drainage, obliteration of cavities, general supportive measures and, when necessary, the removal of the diseased tissue. Certain anatomical peculiarities, however, in addition to a knowledge gained by experience, make it necessary to consider in a somewhat detailed manner how these fundamental principles can best be carried out. But it is also obvious that in the short time allotted for a paper of this kind only certain details can be considered.

A considerable number of cases of pulmonary abscess will heal spontaneously if allowed an opportunity to do so without the interference of a surgeon. Just how frequently spontaneous healing occurs it is impossible to say, because doubtless many of those which heal themselves without interference are not diagnosed. But from our own experience I am certain that many pulmonary abscesses are healed spontaneously without any treatment whatever, probably 25 per cent. or more. These are usually the cases in

[1] Read before the American Surgical Association, May 12, 1927.

which adequate drainage is accomplished by the rupture of the abscess into a large bronchus. They are therefore usually the cases in which the abscess is situated near the root of the lung instead of at its periphery. Complete rest in bed is of the greatest importance in the treatment of an acute pulmonary abscess. This matter has been stressed by Pritchard and by Miller and Lambert, and we agree heartily with them.

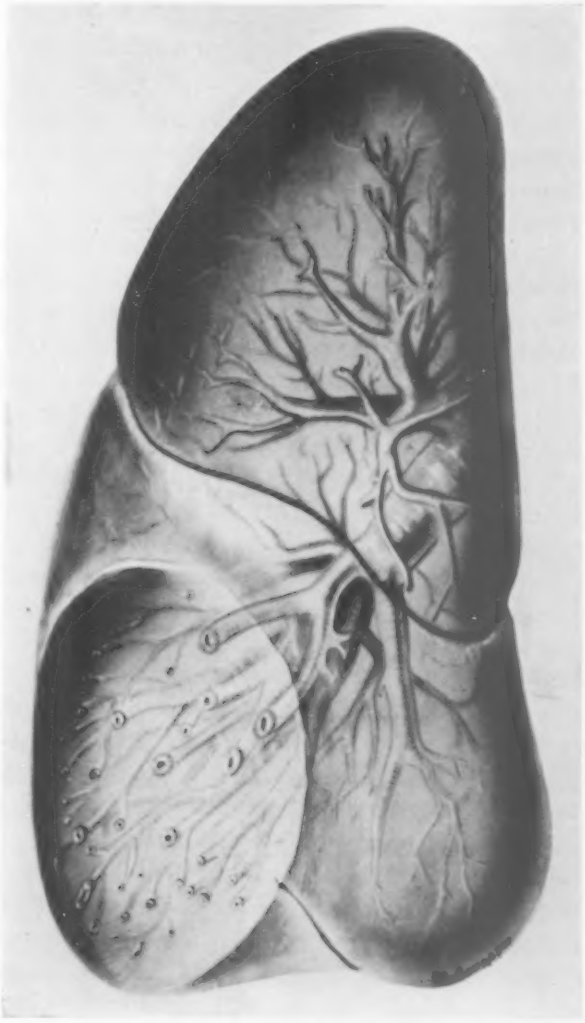

FIG. 1.—Diagram of operation of cautery pneumonectomy to show how massive drainage and gradual extirpation of the diseased portion of lung can be accomplished. Pressure can also be accomplished in any desired degree by the amount of packing in the wound.

It seems perhaps unnecessary to state that the treatment of a case of pulmonary suppuration should begin with a diagnosis. This diagnosis should include not only the obvious feature of the location of the lesion, but also such additional features as the presence of tubercle bacilli in the sputum, of large numbers of spirochetes in the washed pus coughed up, the presence of a foreign body either aspirated or spontaneously formed as a broncholith, the possibility of concurrent malignant disease of the lung, the association of complications, such as meningitis, brain abscess, empyema, pericarditis, etc. It is beyond the scope of this short paper to discuss the ways and means of diagnosing these various aspects of a case, but a mere enumeration of them illustrates the advisability of special training and experience in the handling of these cases.

There seems in many cases, particularly the chronic ones, to be an important relationship between suppuration in the nasal sinuses and suppuration in the lung. It is often astonishing to see the marked improvement

which occurs in a case of chronic pulmonary suppuration after the correction of suppuration in the nasal sinuses. Many of those cases associated with spirochetal infections become healed in a very dramatic manner merely by the administration of an intensive course of treatment with neosalvarsan. It is becoming more and more evident that such cases are much more frequent than was formerly supposed. In the experience of Singer and myself during the last year as many as 74 per cent. of our cases were found by Doctor Varney of the department of bacteriology to be associated with large numbers of fusiform bacilli or spirochetes in the sputum. Not all of them, however, will respond to treatment with neosalvarsan. Many of the cases initiated by the aspiration of a foreign body will recover promptly after the removal of the foreign body, but again not all.

There are various ways by which drainage may be improved. The simplest is by posture. Another is by the bronchoscope. It may be stated in passing, however, that too much reliance should not be placed upon this instrument as a therapeutic agent except for the removal of foreign bodies. The bronchoscopists must yet demonstrate its effectiveness in the treatment of pulmonary suppuration. It is astonishing that despite the claims often made for the therapeutic value of this instrument there have been published practically no statistics giving results of treatment. The only series which I have been able to find is that published by Moore [2] of Jackson's Bronchoscopic Clinic. In spite of the large number of cases treated at that clinic by the acknowledged masters in this field, the results in only thirteen cases are given. Of this number, 25 per cent. are reported as cured, 42 per cent. as improved, and 33 per cent. as unimproved. These results seem still less impressive when it is recalled that the very type of case in which the bronchoscope is most effective is the type situated at the root of the lung, the type in which the largest percentage of spontaneous recoveries occurs. Finally drainage may be increased by surgical interference. From an experience based on 329 cases of pulmonary suppuration, exclusive of empyema and tuberculosis, Singer and I feel that the indications for surgical drainage are impelling only in those cases in which the abscess is situated near the periphery of the lung, in those cases in which spontaneous drainage through the trachea has become shut off with a resultant extension of the inflammatory process, and finally in certain of the chronic refractory cases. The mortality will be less if surgical drainage is not undertaken too early. It is extremely dangerous to go through a large œdematous portion of lung in order to reach the abscess. If the abscess has ruptured into the pleural space, often drainage of the empyema will be the only surgical interference necessary.

Compression of the diseased tissue is a very effective means of obliterating cavities and it also may make the drainage more efficient especially if the abscess is near the hilum. The simplest method of inducing compression is by artificial pneumothorax. The best results with pneumothorax are obtained

[2] Moore, W. F.: Bronchoscopic Treatment of Suppurative Diseases of the Lungs. Jour. A. M. A., 1924, vol. lxxxii, p. 1036.

in subacute abscesses which are not located at the periphery of the lung. In the peripheral cases there is danger of rupturing the abscess into the pleural cavity. Artificial pneumothorax, to be effective, must be continued for at least several weeks and sometimes for several months. Other methods of producing compression, as for example by an extrapleural thoracoplasty or by paralyzing the diaphragm on the affected side by avulsion of the phrenic nerve, should be reserved for the relatively chronic cases. More will be said about them below.

Many of the cases which are seen are chronic with histories of their trouble extending back for years. Probably in all cases of chronic pulmonary suppuration chronic abscess and bronchiectasis go hand in hand. In some cases, however, the features of bronchiectasis predominate and in others those of chronic abscess. In any case it seems to me inadvisable to consider radical surgery at once. Many of these cases, even of a duration of years, make surprising recoveries after comparatively simple treatment by such means as pneumothorax, neosalvarsan, the correction of suppurating nasal sinuses, rest in bed, heliotherapy, etc. But in the refractory cases the question always arises as to what type of surgical interference should be performed. As in a chronic refractory infection in any other organ of the body, so here in the lung the most desirable surgical procedure would be the removal of the diseased tissue if it could be done safely. The ordinary operation of lobectomy, even in the hands of an expert like Lilienthal, seems to carry with it too high a mortality to make it a feasible procedure of great applicability. The reason for the excessive mortality (about 50 per cent.) is chiefly that the mediastinum and large raw surfaces on the diaphragm, chest wall, etc., produced by the mobilization of an adherent lobe, are exposed to an infection from the bronchial stump which is unavoidable in a large proportion of cases. To diminish this risk, an operation based on the principle of the two-stage Mikulicz resection of the colon is excellent when it can be carried out safely. To accomplish this the diseased portion of lung is brought outside the chest wall which is closed tightly around it. After adhesions have formed the outside portion is removed with a cautery. This procedure was proposed and carried out by Lockwood [3] in 1922. I have also found it an excellent and safe procedure in one case in which the mobilization and external delivery of the lung could be carried out easily. More recently Whittemore [4] has modified and enlarged the scope of the operation. There are cases, however, in which the mobilization of the lobe could not be safely carried out. These are the cases in which multiple abscesses predominate in the picture and in which there are excessive adhesions the tearing of which would allow the escape of pus.

Another method of removing the diseased tissue is by the operation

[3] Lockwood, A. L.: Abscess of the Lung. Surg., Gynec. and Obst., 1922, vol. xxxv, p. 461.

[4] Whittemore, W.: Treatment of Chronic Bronchiectasis. Boston M. and S. Jour., 1927, vol. cxcvi, p. 182.

which I [5] have described elsewhere which utilizes the actual cautery for this purpose. The operation of cautery pneumonectomy consists, first of an extensive exposure of the portion of lung affected, which is usually obtained by the removal of three or four ribs for a distance of about four inches each. Then, without separating adhesions but, on the contrary, establishing them if none already exist, a large area is cauterized with an actual cautery. At first no attempt is made to burn away a large mass of lung. The idea is rather to establish numerous bronchial fistulas through which massive drainage may be accomplished. At later stages, more and more lung can be burned away if necessary by increasing the depth of the cavity; but after providing for a few weeks such massive drainage as can be accomplished by the many bronchial fistulas, it frequently happens that much less lung tissue needs to be destroyed than was at first thought. These cases, after all, present only inflammatory lesions. The necessity of removing completely all diseased tissue is therefore not so great as if they were cases of malignant tumors. In my own experience in forty-five refractory cases of chronic suppuration treated by this method the control of hemorrhage has not been difficult. Large vessels that bleed during the cauterization are usually clamped and ligated. The wound is packed to avoid further bleeding. Bleeding even from the large vessels is easily controlled by packing because the blood-pressure in the pulmonary artery is usually only about 20 or 25 mm. of mercury. As a rule the packing is not disturbed for four or five days and an interval of at least two or three weeks is allowed to elapse between cauterizations. In more than 100 extensive cauterizations performed in the forty-five cases only once did a fatal hemorrhage occur. That was in a child whose hemorrhage occurred at night on the twelfth post-operative day. If the

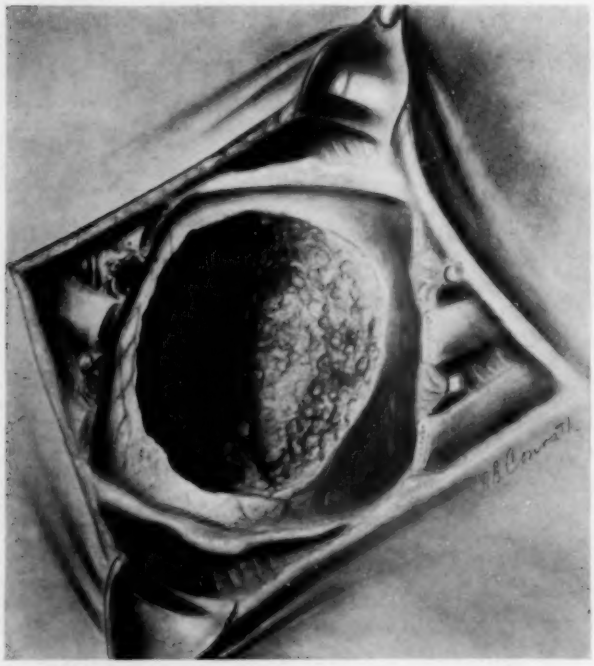

FIG. 2.—Drawing made at operation immediately after a first cauterization. Note particularly the large exposure and the accessibility of the cavity to packing.

[5] Graham, E. A.: Cautery Pneumectomy for Chronic Suppuration of the Lung: A Report of Twenty Cases. Arch. Surg., 1925, vol. x, p. 392.

patient had been an adult, the hemorrhage almost certainly would have been recognized early enough to allow its control with packing. Those who have had trouble with hemorrhage in this procedure have probably made the mistake of not having had a sufficiently large exposure, or of attempting to remove too much lung tissue at one cauterization.

The method, therefore, combines in one procedure all the known effective principles in the treatment of chronic pulmonary suppuration; namely, drainage, compression and extirpation of the diseased tissue. In fact, it accomplishes each of these principles perhaps more effectively than other procedures. The drainage is copious because of the cross-section of the bronchial tree and the creation of multiple bronchial fistulas. Likewise, compression of the affected portion of lung probably can be carried out more effectively and more precisely by this method than by pneumothorax or thoracoplasty, because the degree of pressure can be regulated simply by the amount of packing in the wound. Finally, as regards extirpation, since the lobe does not need to be mobilized there is no exposure of mediastinal pleura, pericardium, etc., to infection such as occurs in the case of the ordinary lobectomy. The chief factor in the operative mortality of lobectomy, suppurative mediastinitis, is therefore absent in this procedure. On the contrary, in the cautery pneumonectomy an effort is made always to stay inside the lung tissue.

Because of the almost complete absence of shock resulting from the operation it is particularly applicable to many cases which otherwise seem hopeless. For example, Singer and I have used it successfully in two cases of very severe bilateral suppuration. We have also used it with a strikingly successful result in the removal of a portion of lung that not only contained a chronic abscess, but was tuberculous as well, in a man, aged sixty-two, who although completely incapacitated and bedridden for two years before his operation, has now been at work steadily for almost two years, entirely free from symptoms.

This operation has been reserved for only the most refractory chronic cases, many of them representing very bad surgical risks. In all we have performed it in forty-five cases. Of this number there have been three deaths which were probably ascribable directly to the operation (a mortality of 6.6 per cent.). One of these was the case of hemorrhage already mentioned above, and the other two were deaths supposedly from air embolism. I cannot, therefore, regard the operation as a particularly dangerous one as judged by other operations for these conditions. One other case died of an acute cardiac dilatation on the sixteenth post-operative day and four other cases died later of suppurations elsewhere in the body. One case died two years later from air embolism after an attempt to close a bronchial fistula, another nearly three years later at home from an unknown cause, but probably from a recurrent infection of the lung, although the patient had been perfectly well for more than two years, and another one two years after the

operation supposedly from meningitis, indicating also, as in the preceding case, that some remaining infected tissue had caused trouble later. In all, eleven, or 24 per cent., of the forty-five cases are now dead from all causes during a period of three years since we began using the operation. Several of these cases were known to be desperate risks, but were operated on in the hope of improving their conditions. On the other hand, thirty-one, or 69 per cent., of the forty-five cases are free from symptoms. Three patients are still in the hospital greatly improved. Of the thirty-one patients free from symptoms, ten have bronchial fistulæ which, however, do not prevent them from carrying on their ordinary activities. It is possible that other procedures may prove to be more effective in certain kinds of cases; but it seems to me that certain cases, particularly the refractory cases of chronic multiple abscesses, can at present be handled more safely and more effectively by this type of operation than by any other yet suggested.

Hedblom [6] has reported marked improvement in a series of cases of the bronchiectatic type of chronic suppuration treated by the operation of extrapleural thoracoplasty; but in the cases which resembled more a chronic abscess his results were not nearly so good. My principal objection to this type of operation is that the diseased tissue is allowed to remain from which recurrences may still occur with the associated danger from hemorrhage, brain abscess, etc. It is not unusual to have symptoms recur a year or two after an apparent recovery if any diseased tissue has been allowed to remain. However, doubtless some cases will be permanently cured by this method; and the operation will probably remain as one of the recognized procedures for suitable cases. Phrenicotomy is often a helpful adjunct to any operation the purpose of which is to produce compression.

In any event the mortality in any large series of cases of chronic pulmonary suppuration will inevitably be high because in about 10 per cent. of the cases there will be an associated carcinoma of the lung, either primary or metastatic, and in about another 10 per cent. cerebral suppuration, either brain abscess or meningitis, will be present.

Various auxiliary measures are important, rest in bed, particularly, neosalvarsan in the spirochetal cases, properly directed heliotherapy, blood transfusions and a liver diet for the anemia (the latter following the suggestion of Murphy and Minot for pernicious anemia), and a high caloric diet.

CONCLUSIONS

Because of the variety of forms of pulmonary suppuration, no particular kind of treatment will be applicable to all cases.

Many cases will heal spontaneously and after comparatively simple methods of treatment, including rest in bed, postural drainage, etc.

[6] Hedblom, C. A.: Graded Extrapleural Thoracoplasty in the Treatment of Diffuse Unilateral Bronchiectasis, 1924, vol. viii, p. 394.

The efficiency of the bronchoscope as a therapeutic agent, except in those cases associated with a foreign body, must yet be demonstrated.

Surgical drainage is applicable only to certain cases.

Various methods of compression are helpful in many cases.

In certain chronic refractory cases it seems desirable to remove some of the diseased tissue. For this purpose, safer improvements over the ordinary operation of lobectomy seem to be offered in the procedure of cautery pneumonectomy and in the modified lobectomy carried out by Whittemore. A series of forty-five cases in which the operation of cautery pneumonectomy has been carried out is discussed in which it is shown that in thirty-one cases, or 69 per cent., there is freedom from symptoms.

MECHANICAL PRINCIPLES OF THE OPERATIVE TREATMENT OF PULMONARY TUBERCULOSIS*

By Howard Lilienthal, M.D.

of New York, N. Y.

The mechanical principles of operations intended to influence favorably the course of tuberculosis of the lungs are factors in achieving two main objects: I. To produce immobility of the diseased parts, and II. To carry out of the body tuberculous exudates and discharges; in other words, to secure drainage.

But I and II invariably supplement each other and, inseparable from surgery, is physiology, especially the physiology of repair.

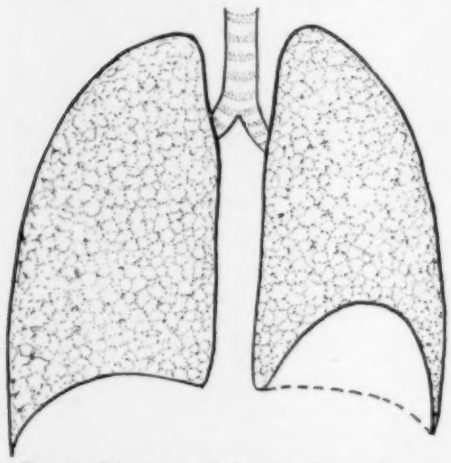

Fig. 1.—Diagrammatic drawing of coronal section of chest from front. The left diaphragm is elevated because of interruption of phrenic nerve impulses. Reduction of pleural capacity equivalent to from two to five hundred cubic centimetres of pneumothorax.

I shall discuss in this paper the mechanics alone, knowing that my hearers are already acquainted with the other influences which bear upon the disease and its pathological anatomy.

I. *Surgically Induced Rest.*—This may be of two varieties: A. Temporary rest—when the lung is not hopelessly diseased and may be expected to resume its function at the end of the treatment.

B. Permanent rest—with or without complete obliteration of the pulmonary air spaces both normal and pathological. This principle is to be applied when disease has advanced to such a degree that attempted reëstablishment of function will tend to produce an exacerbation of the tuberculosis.

A. Temporary Rest.—This may be accomplished by (1) an extrathoracic or (2) by intrapleural procedure, the effect of either being accompanied by a temporary reduction in pulmonary air volume.

(1) Extrathoracic procedure: The method referred to here is the ingenious device of Yates (*Archives of Surgery*, vol. xiv, No. 1, Part 2, pp. 369 to 380), who finds that by crushing the phrenic nerve with forceps the corresponding half of the diaphragm may be temporarily paralyzed so that it rises into the thorax, thus producing a partial collapse of the lung.

Judging by clinical results and röntgenographic appearances I conclude

* Read before the American Surgical Association, May 12, 1927.

that the elevation of the diaphragm may effect a reduction in capacity the equivalent of from 200 to 500 c.c., more or less. This is not, however, the exact mechanical effect which pneumothorax of low tension produces for reasons which will be given farther on. Still both the capacity and the respiratory excursions of the lung are diminished by the procedure. (Fig. 1.)

This minor operation which Yates has designated by the name of *phrenemphraxis* is effective for a few months only, when gradually the function of the diaphragm is restored.†

During this period repeated transfusions and general hygiene are employed. In addition, the reduction in pulmonary capacity is accompanied by an increase in the proportion of blood delivered to the lung, a great advantage in the cure of tuberculous lesions.‡

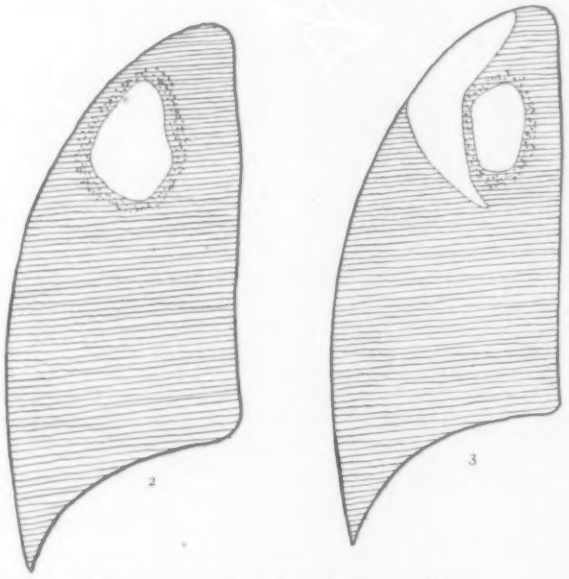

FIG. 2.—Infiltration and cavitation of right upper lobe.
FIG. 3.—Same case after introduction of 300 c.c. of air into the right pleura. Patient erect. Localization of the air in the upper chest.

(2) Intrapleural Procedure: The one most frequently employed is the production of artificial pneumothorax. In proportion to the degree and character of the lesion this therapy is varied so that we have either full collapse and even compression of the lung with almost no respiratory function, or very slight collapse without actual compression. The latter, particularly in the early cases, often has an apparently selective effect placing at rest the diseased part of the lung while merely diminishing the function of the normal areas.

This selective action has been well described and explained by Bendove (Raphael A. Bendove, *Archives of Surgery*, vol. xiii, No. 3, p. 369), who, with a series of skiagrams, beautifully demonstrates the action of this form of pneumothorax.

Briefly, the explanation is based upon the fact that the infiltrated foci do not fill with air on respiration while the surrounding healthy lung expands and contracts. This, to be sure, probably happens to a less degree even without pneumothorax, but it cannot be demonstrated to the eye. Figures 2, 3, 4 and 5 are diagrams drawn from illustrations in Bendove's paper.

The selective action of low tension pneumothorax is the point previously

† Permanent paralysis may, rarely, be produced by contusion of the nerve.
‡ Cloetta, quoted by Yates, *loc. cit.*

referred to in discussing the effects of phrenemphraxis. While the reduction in capacity may be the same, the pneumothorax has the advantage of the selective distribution just described. (Figs. 2, 3, 4 and 5.)

In cases of more extensive disease, it is usually advisable to produce more general collapse in an effort to set at rest the entire lung and this is done by increasing the volume of air within the pneumothorax until in complete cases the lung is not only collapsed, but may be compressed from all sides into a small atelectatic body or may be converted into a thin mass lying along the spinal gutter.

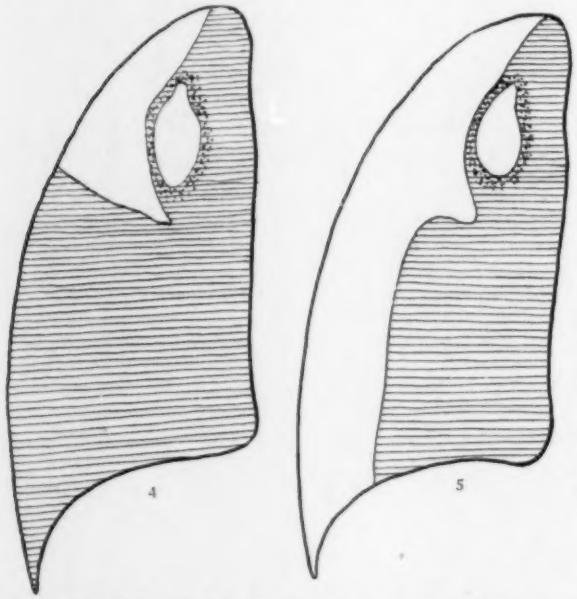

FIG. 4.—Same case in full inspiration nine days after initiation of pneumothorax; the diseased upper portion is compressed and the lower functioning portion expands and contracts with respiration.
FIG. 5.—Same case in expiration. Note motion of lower part of lung away from chest wall.

The air, however, is gradually absorbed, the lung slowly expands and if no more air is insufflated, there is a return to the normal filling of the chest and the usual negative pressure. It is, therefore, necessary to refill every few weeks in order to maintain the lung at comparative rest.

In spite of its undoubted benefits, pneumothorax possesses the disadvantages incident to frequent thoracic puncture with the well-known complications of intrapleural effusion or tuberculous infection of the chest wall or both. Indeed, when mixed pleural infection appears, the complication may be a particularly dangerous one. On the contrary, in favorable cases, clinical cure is by no means rare. In any event full therapeutic pneumothorax is usually followed by great improvement in the general state of the patient and in the symptoms of his disease.

It has been suggested that a thin neutral oil might be employed instead of air or other gas as a compression medium in the pleural sac, the principal gain being that the necessity for refilling would be eliminated. This would be on the same mechanical principle as that present in the serous pleural effusions which so frequently occur in pulmonary phthisis. The method has never been given a thorough trial, although it has been experimentally used by Archibald and by Parfitt (Transactions of the National Tuberculosis Association for 1922, pp. 194 and 195). It has also been tested by me in non-tuberculous lung suppuration following intrathoracic operations. Here, in the presence of infection, it was useless and had to be withdrawn. The

late Kenneth MacKenzie, of Portland, Oregon, once said to me that he had used it experimentally in rabbits and that its presence was well borne.

Others have used medicated oil. M. G. Kuss (*Revue de la Tuberculose*, February, 1926, vol. vii, p. 100) and A. Bernou (*ibid*, June, 1926, vol. vii, p. 23) report on the use of oleothorax with medicated oil, especially in cases of spontaneous pneumothorax following artificial pneumothorax.

Adhesions or general synechiæ of visceral and parietal pleura may vitiate the result in artificial pneumothorax or may even prevent the treatment from being carried out.

Air, by its continuous elastic pressure, will tend to break down gradually or to attenuate adhesions until they have disappeared and full collapse can be secured. Pneumothorax should, therefore, be given extended trial. (Figs. 6 and 7.) It must also be remembered that certain adhesions which apparently do not yield to air compression may be severed with the aid of Jacobaeus's thoracoscope or even by opening the thorax and dividing the adhesions under the eye, afterward closing the chest. Eloesser, of San Francisco, has successfully performed this operation (*Archives of Surgery*, January, 1927, Part 2, p. 441). While this is not the place to discuss the merits of either of these procedures, their obvious dangers must be contrasted with the advantages of saving the function of the lung.

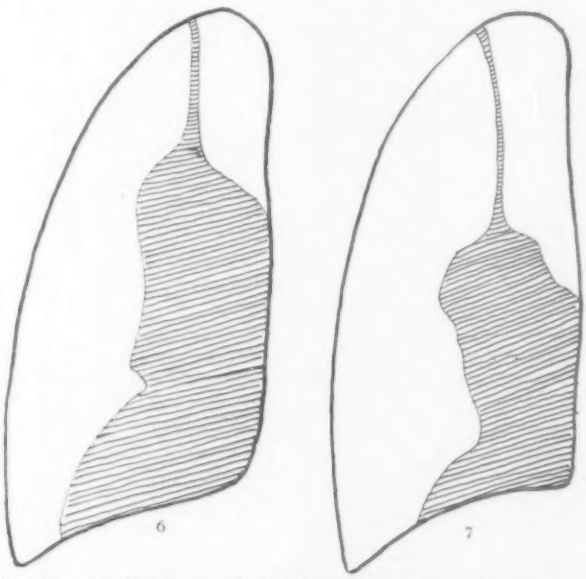

FIG. 6.—Partial collapse of right lung three weeks after pneumothorax was induced to control hæmoptysis. Cord-like apical adhesion suspended from the dome of the pleural cavity. (This figure and the following are from a paper by Amberson and Peters in *Thoracic Surgery*, Saunders, 1925.)

FIG. 7.—Better collapse of right lung with stretching of apical adhesions under slightly positive pressure (2 cm. of water). The adhesions finally gave way and complete collapse was secured.

B. *Permanent Rest*,—The test of cure after temporary rest comes, manifestly, when the lung is again permitted to function. In some cases fibrosis will prevent expansion. In others, particularly when pleural infection has been present, expansion may fail because of organized exudate upon the visceral pleura. In still others pulmonary fibrosis may prevent reëxpansion yet, finally, expansion may occur but always with a lighting up of the disease. In the latter instance the mechanical action of the intrapleural pulmonary compression may be satisfactory, but the dangers and annoyances of the constant refills may make it advisable to place this lung permanently

at rest, even though the pneumothorax may bring temporary relief. It would seem that this class of cases would be the ones for which a non-absorbable medium might be most desirable.

A first step in producing permanent rest for an incurable lung is phrenic nerve avulsion, an operation preferable to mere section or resection because accessory nerve fibres are thus eliminated which, if permitted to remain, vitiate the desired result of a paralytic diaphragmatic elevation.

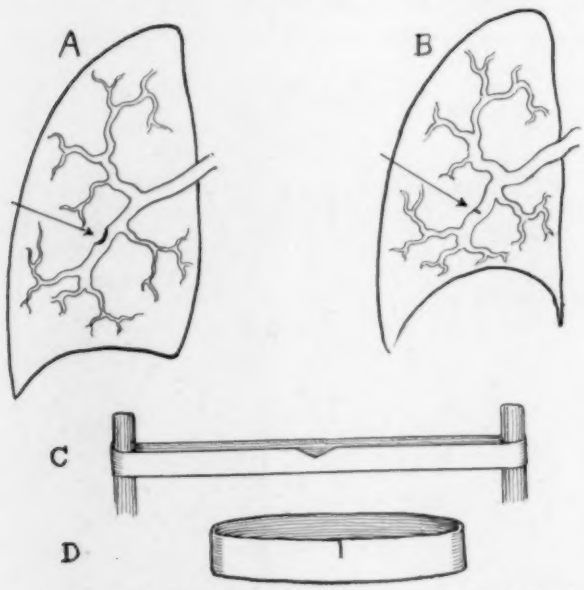

FIG. 8.—*A*. Lung under normal negative pressure. The blood-vessels are stretched. The arrow points to an ulceration in a vessel. *B*. Represents the same lung the tension relaxed by the elevation of the diaphragm. The wounded vessel shortens and the opening in its wall is closed. *C*. Represents a rubber band on the stretch with a nick in one edge. *D*. Same rubber band no longer under tension. The sides of the nick have fallen together.

I have elsewhere¶ described this procedure and need not enter into its details here except to state that it is not ordinarily a dangerous one and that, if performed through a transverse incision upon the clavicle the resulting scar is almost invisible. Very great improvement may follow this operation including the cessation of hæmoptysis. (Fig. 8.)

Nature seems to make an attempt to create rest in early tuberculosis when on fluoroscopy the diaphragm of the affected side reveals diminished motion or even rigidity in the presence of a small area of apical disease.

The commonest and most universally applicable method is that known as Sauerbruch's paravertebral thoracoplasty. The operation is well known to surgeons and need not be described here.

FIG. 9.—Dr. Ralph Matson's rib stripper and raspatory.

As a note in technic, I call favorable attention to a rib stripper, the invention of Dr. Ralph Matson, of Portland, Oregon. I have used it many times, always with the pleasure a workman finds in an excellent tool. The instrument is shown in Fig. 9.

The mechanical action of Sauerbruch's thoracoplasty deserves a little discussion.

Resection, or even the mere division of the ribs near the spine, is followed by a variable but often great reduction in the size of the thorax because

¶ Thoracic Surgery, Saunders, 1925.

the ribs quickly assume a slant more nearly vertical than their normal obliquity. There is also a true depression of the ribs which is sometimes very marked, particularly of that part between the spine and the anterior axillary line. This is seen in its greatest degree in the upper ribs, especially the first, where a small resection, only about one-half inch, is frequently followed by a dropping of the now movable portion of this bone, so that its posterior extremity is at the level of the second interspace or even the third (Fig. 10), thus permitting nearly the entire apex above the line of the clavicle to fall below this line. Muscular and tendinous attachments between the clavicle and the first rib hold the latter bone in its normal position and, in turn, the intercostal structures are in a great measure responsible for the support of the ribs below, especially the first four or five.

FIG. 10.—Dropping of the first rib to the third interspace following paravertebral thoracoplasty. The lower ribs have also dropped. Note their increased slant. Apex of lung above clavicle has disappeared.

In order to gain the greatest effect in reducing the capacity of the upper thorax it is, therefore, essential that the first rib should be resected or at least divided, and this should be done in the first stage of the thoracoplasty. Direct union of the cut ends of this rib rarely if ever occurs. It drops, as just stated, to the second or third space. In addition to the drop of the ribs following resection of their posterior portions, there is partial rotation which is permitted by the flexibility of the cartilages and, as the divided ribs become oblique, they approach each other in the axillary line and behind it even to the point of overlapping.

The full collapsing effect of this operation may not be manifest at first and its progress may continue for months or even a year. This is particularly the case in the lower chest where the longer costal sections have been removed and where union is often delayed. Patients in whom the lower chest-wall continues to move with respiration sometimes complain of painful or uncomfortable sensations as a result. This can be helped by wearing a firm support such as the strong elastic adhesive plaster known by the trade name of Elastikon (Johnson and Johnson).

In addition to the action of the trunk muscles, I am convinced that the

steady negative pneumatic pull within the thorax is of much assistance in bringing about the desired contraction. This suggests one of the reasons for the difficulties encountered in obliterating a pneumothorax which is in direct connection with the outer air, whether through the chest-wall or through the bronchial tree; also the persistence of pulmonary cavities of large size which nearly always communicate with the outer air by way of the bronchi. I do not think that this point has been brought out before. It will be referred to farther on.

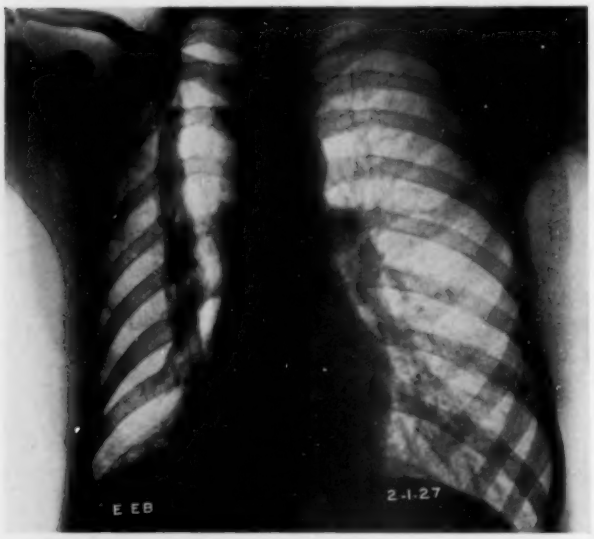

FIG. 11.—Late result of thoracoplasty illustrating fusion of ribs from top to bottom of chest producing great rigidity of thoracic cage. Note staggering position of ribs no end-to-end union. This operation was done for a non-tuberculous, general suppurative bronchiectasis of right chest. Clinical cure.

The usual cases in which thoracoplasty is performed are those with cavities of not excessive size. Collapse here is generally prompt and efficient while in the presence of large apical cavitation the proportion of collapse in the lower two-thirds of the chest is much more pronounced than it is in the upper part, so that it is frequently necessary to perform additional operations such as apicolysis for direct compression. In tuberculous empyema with full contraction of the lung and with drainage through an external fistula the chest wall must be actually caved in by a series of operations in order to obliterate the dead space.

Occasionally the opposite lung becomes the seat of compensatory emphysema deviating the mediastinum toward the collapsed lung or pleura, thus aiding in this obliteration.

Contrary to the operative indications in non-tuberculous empyema, in which everything is done to bring the lung to the chest wall, in tuberculous lung this is undesirable for an immediate increase in cough and expectoration will follow for reasons to be given later.

It is not the mere collapse or compression of the lung which produces the arrest of the tuberculous process so much as the limitation or abolition of respiratory movement. So that the degree of collapse in ordinary cases without pneumothorax or empyema need not be so great as that which is requisite when these complications are present. Indeed, in tuberculous pneumonia there may be very little collapse, the improvement being brought about almost entirely by immobilization.

Let us assume that there is a pneumothorax, closed or open. Ordinarily there is respiratory motion in these circumstances, expansion of the lung occurring with expiration instead of with inspiration. Still, the mere presence of motion, however little, is a disadvantage. I have seen cases of closed empyema with pulmonary compression in which there was little or no expectoration and but little cough, but in which cough and profuse expectoration occurred the moment that external drainage by thoracotomy was established. This increase in expectoration will, however, greatly diminish as the

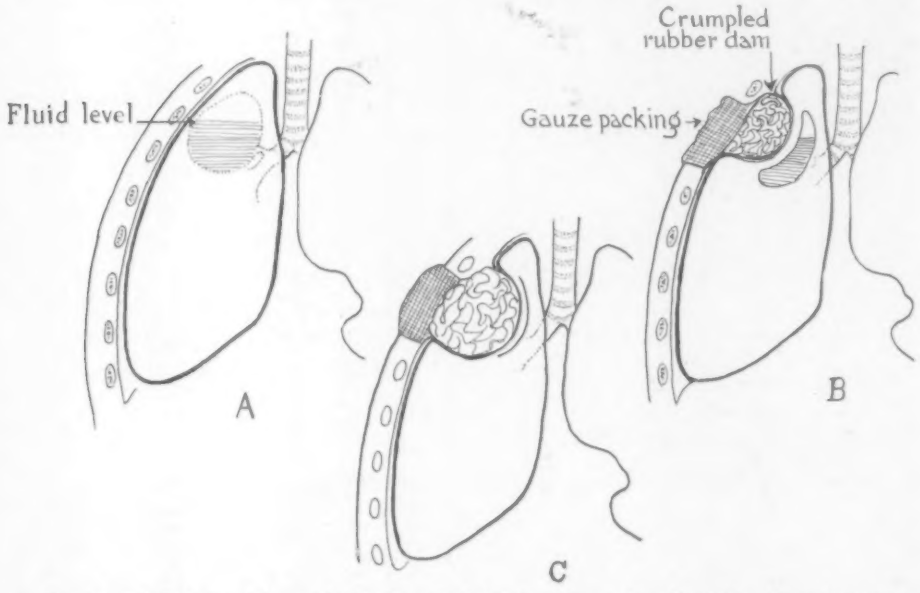

FIG. 12.—*A*. Represents large apical cavity. *B*. Subperiostial resection of two ribs. The soft parts including periosteum forced inward. The extrapleural cavity thus formed is firmly packed with crumpled rubber dam, a pad of gauze on the outside to hold the rubber in place. The section of the cavity now has become crescentic. *C*. Four days later, the elastic expanding force of the rubber has greatly enlarged the extrapleural space compressing the pulmonary cavity into a curved slit. (See text.) Note: In typical apicolysis the entire pulmonary apex is pushed downward, not as represented here.

pleural exudate stiffens holding the lung in greater rigidity. It will, of course, be understood that in closed pneumothorax we are dealing with a compressible medium instead of an incompressible one such as pus or serum. Therefore, in open pneumothorax or more usually pyopneumothorax, such as is found in drained tuberculous empyema, it is but necessary to obliterate completely the dead space if we are to attain immobility of the lung; or motion of the lung may be already limited by confining membrane so tough and fibrous that respiratory motions are negligible.

II. *Drainage.*—Surgical drainage in pulmonary suppuration may be divided into two classes: A. Drainage through the bronchial tree by way of the mouth (obliteration). B. Direct drainage through the chest wall.

A. *Drainage of Pulmonary Cavities by Obliteration.*—Let us suppose that the patient is expectorating freely from the cavity itself but on account of its form or its position this cavity cannot be continuously emptied. If

the lung contains many of these spaces and its contents cannot be effectively evacuated by the more usual intrapleural means such as pneumothorax, posture, etc., clearly some form of thoracoplasty will be demanded. Not infrequently, however, we find a single large cavity in the upper chest with the lower part of the lung revealing little evidence of disease and well able to function. The mechanical principle here employed would depend upon the possibility of draining the cavity through the bronchus by forcible compression. If this is not possible and the patient suffers from cough with profuse expectoration or toxæmia, drainage into the outer world by pneumonotomy must be secured. Both these methods will be briefly discussed.

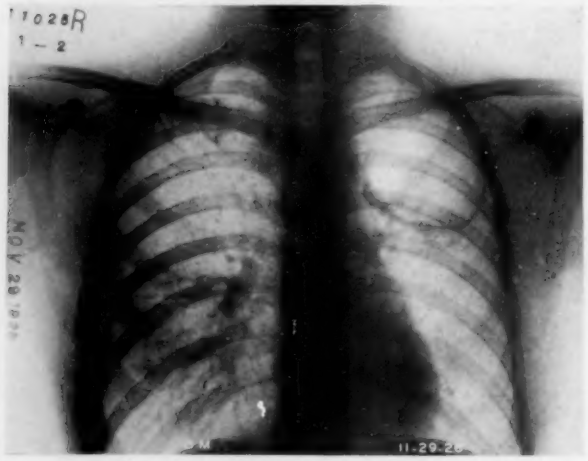

FIG. 13.—A case in which the procedure (Fig. 12) was employed. Enormous upper lobe tuberculous empty cavity. (Seen from in front.)

Mechanical Compression.—The first attempt should be by posterior thoracoplasty of the upper five or six ribs. If this does not produce sufficient reduction in the size of the cavity an extrapleural direct compression should be attempted. Now, in complete thoracoplastic operations it is often found that a large upper lung cavity has not been obliterated, although the lower part of the chest shows great reduction in capacity. An explanation for this phenomenon has been offered in a former paragraph, but may be repeated for emphasis. Ordinarily the negative pressure within the pleural sac tends to contract the thorax when the ribs have been mobilized. This suction being absent in the cavity because of normal air pressure, the original

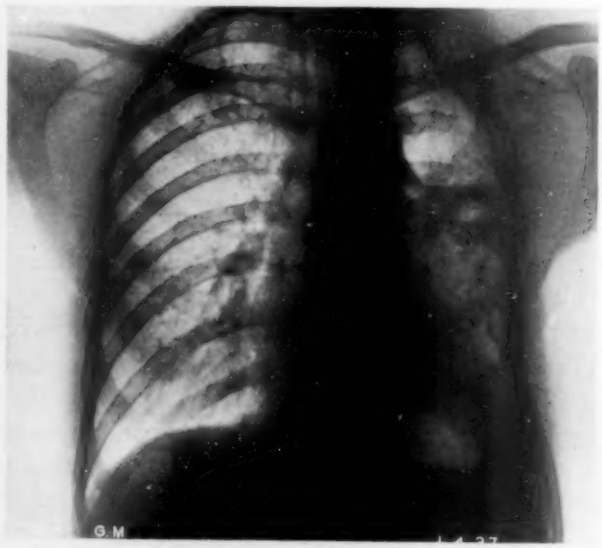

FIG. 14.—Same patient following thoracoplasty of upper eight ribs. Two fluid levels are now seen. Note that collapse is less efficient in the upper chest than below.

volume of the latter shows little tendency to reduction. The space must, therefore, be forcibly obliterated. The methods which promise the best results are known as Apicolysis, by which an extrapleural space is made, the upper part of the lung being pushed downward and inward, and is permanently maintained by a plug of foreign material, the chest wall being then completely closed. In a modification of this procedure the extrapleural space over the cavity is filled with a packing, leaving the wound open. The packing is changed every two or three days until cicatricial tissue has formed, together with new bone from the dislocated costal periosteum. Thus a firm barrier is secured which prevents the reëxpansion of the cavity.

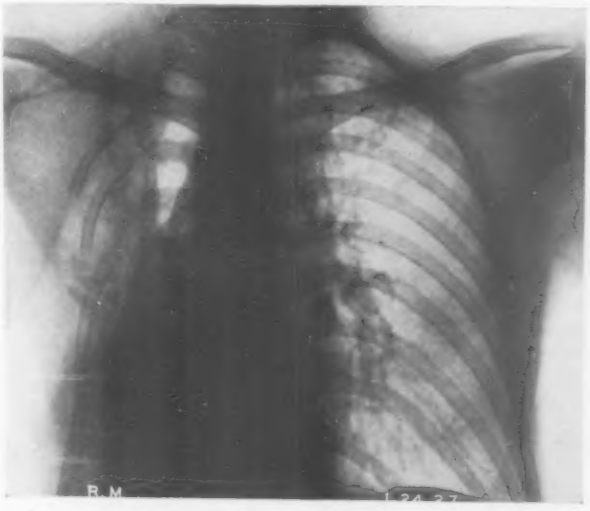

FIG. 15.—Same patient (seen from behind) modified apicolysis has greatly reduced the cavity. In transverse diameter this has been reduced by about three-quarters. In cubic capacity the reduction is, of course, very much greater. This picture was made soon after the operation. The cavity has since become a mere slit.

I have found that in performing this type of apicolysis the use of a crumpled plug of rubber dam pushed firmly into the extrapleural cavity and covered with a gauze packing, the whole held in place by temporary skin sutures for three or four days, will greatly increase the efficiency of the apicolysis. In four days, when the sutures are removed and the gauze and rubber dam taken out, it will be found that we have secured a much larger extrapleural chamber than that which was made at the time of the operation. The rubber dam packed in this manner exerts a strong elastic force gradually but surely enlarging the space which it occupies. (Fig. 12.)

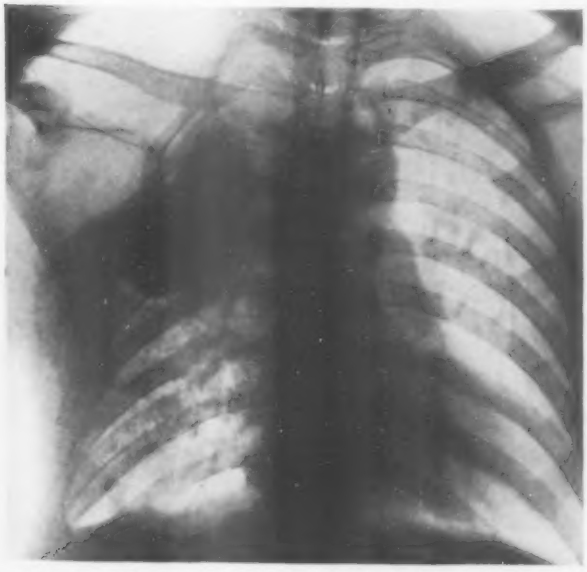

FIG. 16.—Apicolysis with iodoformized wax filling. (See text.)

I have found this method of filling an uper half thoracoplasty in apicolysis efficient, although the period of convalescence, with the frequent packings, is long and may become irksome. As soon as the wall of the cavity no longer approaches the surface when the patient strains or coughs, the packing may be omitted and the wound allowed to close. A deep depression lined with skin marks the final result. Figures 16, 17 and 18 exemplify a case in which this method was employed. Figure 16 shows an iodoformized temporary wax filling in place, which I then employed instead of the preferable rubber dam.

FIG. 17.—Photograph of patient after apicolysis.

Figures 17 and 18 are photographs of the patient after recovery. The lower part of the lung is functioning perfectly and the patient is clinically well. He has married with the approval of Doctor Waters, of Loomis Sanatorium, a most conservative physician.

Another method, not quite so radical as those just described but much simpler and, in suitable cases, quite efficient, was first described by Dr. E. S. Welles, of Saranac Lake (*Archives of Surgery*, vol. xiv, No. 1, Part 2).

I have applied this method in three cases with good immediate results. Its technic is simple and there is the additional benefit that it requires but a few days of hospitalization. Briefly, the operation as I have performed it may be described as follows:

With the patient's arm above the head, the incision is made from near the apex of the axilla down along the anterior axillary line. When desirable this incision may be continued around the lower mammary fold so as to conceal an otherwise obtrusive part of the scar. (Fig. 19.) The posterior flap is dissected away from the ribs and the anterior flap is retracted, lifting the mamma from the pectoralis major muscle as far as may be necessary. The patient's arm is then placed against the chest, thus loosening the border of the pectoralis major which can now be retracted far toward the median

FIG. 18.—Same case, lateral view.

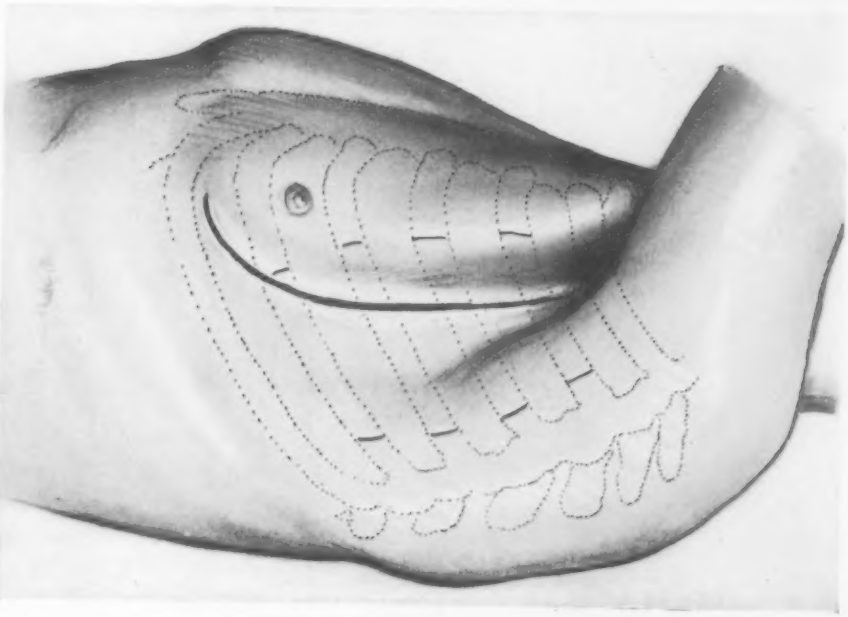

FIG. 19.—Welles's thoracoplasty. Left paravertebral thoracoplasty has previously been done. The mass of fused intercostal bone is seen in front of the vertebral spines. Dotted lines diagrammatically represent the ribs, the short solid lines indicating the present resections.

line, affording plenty of space for the remainder of the operation. Sections of the ribs, as many as seem necessary, are then removed, stopping short of the costal cartilages, but going back as far as the union of the ribs which followed the original thoracoplasty. All periosteum is conserved. The pleura, of course, uninvaded, is carefully stripped from the ribs and the flaccid chest wall being pushed inward and backward, a deep depression is formed over the entire exposed area. Immediately there is free motion of this part of the thoracic wall, the area being sucked in on inspiration and forced out on expiration. The two flaps formed by skin and underlying tissues are united with a few interrupted through-and-through sutures and more perfect approximation is made with metal clips or fine silk stitches. A narrow tube to drain away the serum is led out of the lower part of the wound and may be removed in forty-eight hours. Gentle but firm gauze pressure is applied as a dressing and held in place with elastic adhesive plaster (Elastikon). Union will be sufficiently firm in four or five days to permit the beginning of the next stage in the treatment which is to exert continuous elastic force upon the mobilized part of the thorax and to maintain its concavity until the formation of bony plates from the mobilized costal periosteum shall have stiffened the walls to resist coughing and straining. This is accomplished by enclosing a large crumpled mass of rubber dam or a rubber bath sponge in a gauze covering and strapping it in place with adhesive plaster. (Fig. 20.) The gauze covering should consist of several layers and is used so that the skin will not become macerated by contact with rubber. Figure 22 is from a photograph of one of my patients.

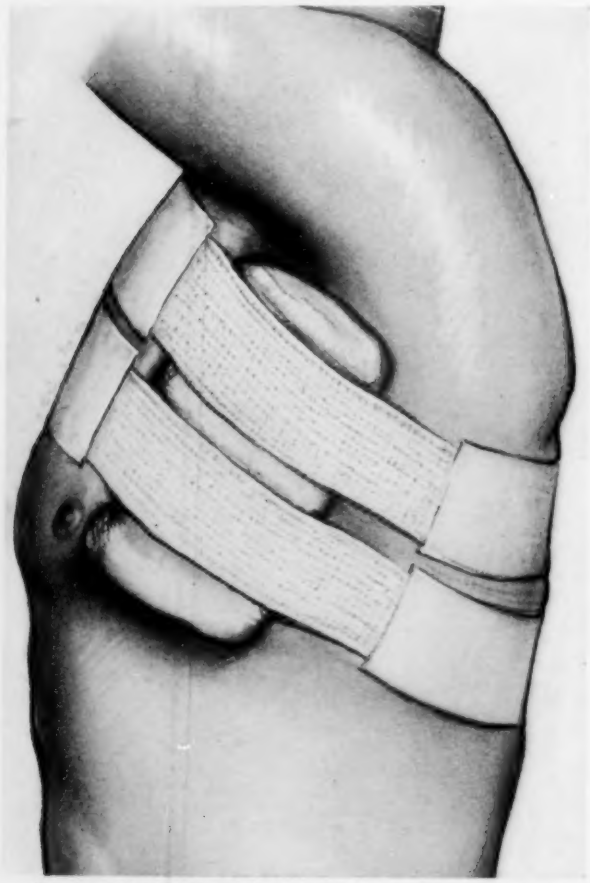

FIG. 20.—Compressing pillow of rubber dam and gauze maintaining the hollow formed by Welles's thoracoplasty. Pillow held firmly by strips of elastikon reënforced at each extremity with adhesive plaster.

I have not made use of this procedure as a primary operation to obliterate an apical cavity and I think its application here would be very limited. My cases have all followed paravertebral thoracoplasty.

B. *Drainage of Pulmonary Tuberculous Cavities Through the Chest Wall.*—Opening a tuberculous cavity in the lung should be avoided if drainage by compression can be accomplished. It is not, however, the calamity which it was formerly believed to be. Sauerbruch, having accidently caused a perforation, made the best of it and found that the drainage thus afforded was of considerable benefit.

FIG. 21.—Wound healed and result of compression demonstrated.

In one of my cases when the bronchial exit of a cavity became angulated or plugged as the result of a distortion by paravertebral thoracoplasty, the patient at once became profoundly septic with high fever and I was forced to drain. This I did by resecting a rib contiguous with the thoracoplastic wound and entering bluntly the now putrid abscess which before had been recognized as a typical tuberculous one. This patient has done extremely well and healing proceeded slowly, but so steadily that it became difficult to maintain the fistula which finally closed. It is more than four years since the operation. The patient is afebrile most of the time and is up and about, but there is still some irritative cough. She is well nourished and X-ray study indicates that the walls of the cavity are probably in contact.

It is interesting to observe that this opening into a chronic tuberculous hollow within the lung showed an almost unpreventable disposition to close. I believe that, with our present knowledge of phthisis, the actual drainage of cavities of this kind should be a last resort, but that we need not unreasonably fear it.

III. In tuberculosis of the lungs we also may have to deal with conditions demanding the following:

A. Drainage of the pleural sac, no thoracic opening—(a) without bronchopleural fistula, (b) with bronchopleural fistula.

B. Drainage of an open tuberculous empyema—(a) without bronchial fistula, (b) with bronchial fistula.

A. *Drainage of Pleural Sac When Chest Wall is Intact.*—(1) Without Bronchopleural Fistula: We have here virtually an ordinary empyema on a tuberculous base, with or without mixed infection. These cases are often of extreme chronicity even running into years. The patients are not confined to bed but, on the contrary, may feel well and able to work. It appears to be nature's method for producing intrapleural pulmonary collapse. There is little or no cough. The pleura becomes thick and stiffened and there may be no real reason why anything should be done to change the status.

FIG. 22.—Photograph of a patient upon whom the operation (Welles's) was done. The scar shows an additional skin incision.

With the emptying of the chest, by aspiration or otherwise, there is a tendency for expansion of the diseased lung and this may be followed by a recrudescence of the active tuberculosis.

Occasionally, however, these collections of fluid very slowly increase pushing the mediastinum toward the healthy side and encroaching upon the functions of the mediastinal viscera and the opposite lung. There is increasing dyspnœa, then cyanosis, and if nothing is done for relief, death will follow. When treatment is necessary in these cases, a simple form of valvular drainage is to be preferred to free incision or forcible aspiration.

A method which I have found useful is to insert through a cannula, a multifenestrated small catheter, the cannula then being removed. A very thin finger cot attached to the outer end of the catheter and then nicked with scissors makes an efficient valve, preventing the entrance of air while permitting the escape of fluid and such air as may have accidently been admitted. The end of the tube with the finger cot should hang in a container of some sort, say a small rubber bag or even a test tube, according to the quantity of discharge; but it must be arranged so that air can circulate between the tube and the neck of the bottle or other receptacle. (Fig. 23.)

The patient may be out of bed and soon learns to keep his dressing in order. The physician should make an inspection every few days. The

tendency is for the lung to expand gradually. Cough may appear with or without fever and in this case a thoracoplastic operation is required to obliterate the pleural space and put the lung permanently out of commission. At any rate the problem has now become one of ordinary tuberculous empyema.

(2) With Bronchopleural Fistula: This is usually the result of the perforation of a tuberculous cavity into the pleural sac. There is mixed infection, with air as well as pus present. When there is valvular action of the bronchial fistula a dangerous tense pneumothorax may appear calling for immediate relief by incision or by puncture with a trocar. (See Fig. 23.)

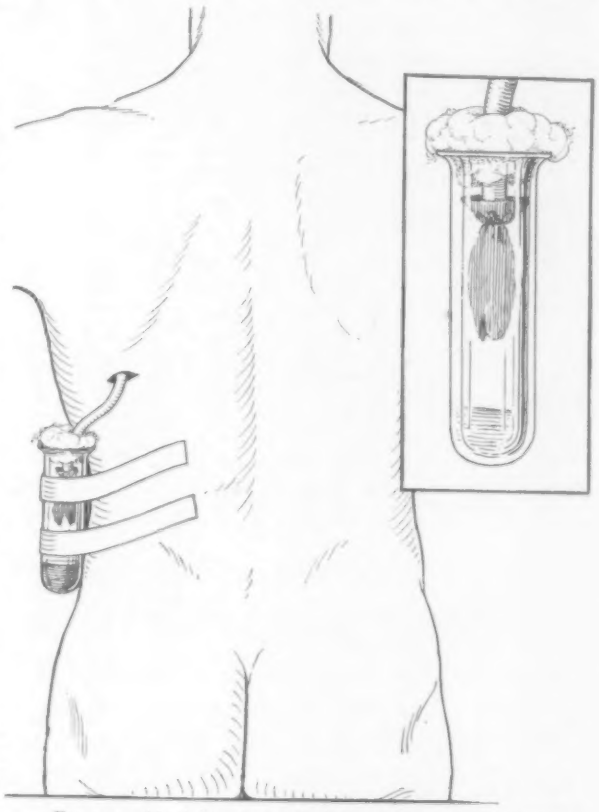

FIG. 23.—Air-tight valvular drainage of tuberculous empyema or of pyopneumothorax, arranged for ambulant patient. This is also applicable to certain nontuberculous cases. The insert is a closer view of the detail.

In any event, when drainage by way of the bronchial opening is insufficient, which is usually the case, thoracotomy with or without rib resection must be performed for external drainage. Subsequent treatment need not be discussed here.

A test may be made of the closure of the bronchopleural fistula by injecting a little dye, such as 1–5000 gentian violet, into the pleura and placing the patient in many postures especially lying in bed with the head low, both prone and supine, and noting whether the sputum is colored by the dye. Then, or even without this test, thoracoplasty may be employed to reduce the size of the infected pleural space or to effect obliteration.

B. *Drainage of an Open Tuberculous Empyema.*—(1) Without Bronchial Fistula: When there is no demonstrable bronchopleural fistula, the problem is to close a simple drained tuberculous empyema. The lung mobilization, so valuable in non-tuberculous pyothorax, becomes here a dangerous and non-permissible operation for, not only will there be spreading of tuberculous infection on account of the reëstablishment of pulmonary motion, but

the opening of many lymph and blood channels in indurated tissue is very apt to be followed by the entrance of air, toxines or even emboli of considerable size with lodgement in distant regions, especially in the brain. The lung and its coverings are, therefore, carefully guarded from traumatism and the chest wall, mobilized by multiple rib resection, is made to approach the midline of the body. (Fig. 24.)

(2) With Bronchial Fistula: In pulmonary tuberculosis with a bronchial

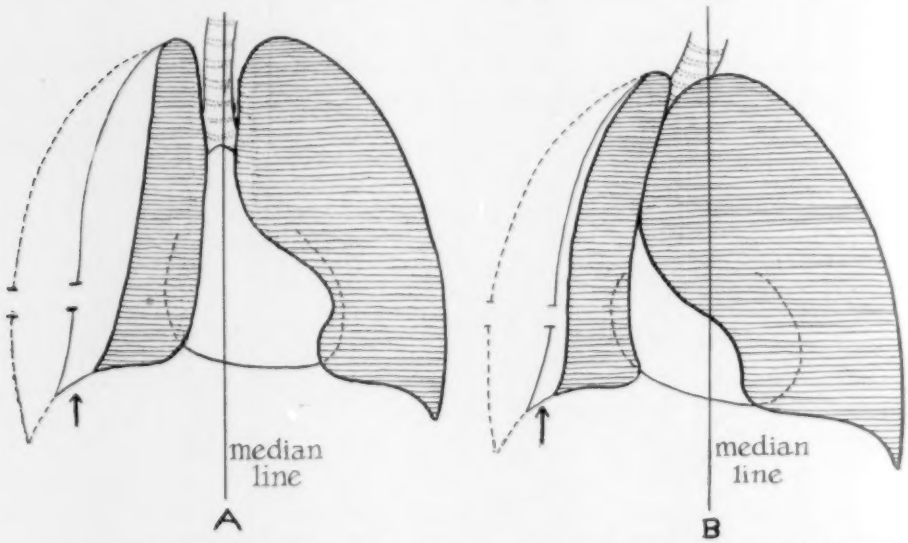

FIG. 24.—Obliteration of simple tuberculous empyema. *A*. Thoracoplasty has moved the normal chest wall (dotted line) toward the midline of the body, reducing the size of the pleural sac. The lung (shaded portion) has been firmly collapsed by the former tense empyema. *B*. Pleural cavity still further diminished by gradual encroachment of the better lung which has pushed the mediastinum and its organs toward the diseased side. (Arrows indicate pleural cavity).

fistula in an open empyema cavity the cure is tedious. It may require many operations to obliterate the pleural sac and the cavity within the lung. This is all which can be done from the purely mechanical side. There must be perfect drainage from the lowermost part of the wound and our hope will then lie in the final obliteration of the recess within the pleural cavity by granulation. No method is known by which the bronchopleural fistula can be mechanically closed so that it will heal. We must depend upon supplying proper conditions for the disinfection of the wound and trust in the restorative power of the tissues themselves to accomplish full repair.

SUMMARY

1. Rest and drainage are the two important mechanical objects of the surgery of pulmonary phthisis.

2. Rest may be temporary and in varying degrees, or it may be permanent in varying degrees even to the complete abolishment of lung function.

3. There are extrathoracic methods. Those relating to the phrenic nerve are described.

4. Operations upon the thorax itself deal with rest and with forms of drainage, either by way of the air passages and mouth or out into the world.

5. The obliteration of pulmonary cavities or of diseased areas of the pleural sac are described. Speaking broadly, this obliteration is a form of drainage.

6. Pulmonary collapse and compression are aided by the suction power of negative intrapleural pneumatic tension. This negative pressure cannot operate when there is an air passage through the chest wall. It cannot operate in the case of large intrapulmonary cavities which directly open into the normal outside air through a large bronchus.

7. Methods of operation are described and there is a discussion of the mechanical principles on which they are founded.

OPERATIONS AS AIDS IN THE TREATMENT OF PLEUROPULMONARY TUBERCULOSIS[1]

By John Lawrence Yates, M.D.
of Milwaukee, Wis.

We purpose to establish three significant but unrecognized facts concerning the treatment of those suffering from pleuropulmonary tuberculosis. (1) To show why simple operations used promptly, in proper sequence, and in conjunction with other measures will provide each patient, not already lethally affected, with every opportunity for undelayed recovery, for arrest or retardation of the progress of his disease, whatever be the nature or the stage of the malady. (2) To show why neither surgical nor non-surgical measures alone can fulfill these therapeutic requirements. (3) To show how beneficent operations have been performed without imposing intolerable burdens upon even weakened patients and with only the limited dangers of wound infection, hemorrhage, thrombosis, embolism, and pneumothorax.

I. Pathogenic tubercle bacilli are deposited so frequently upon epithelial surfaces within the lungs of most adults and many children that their presence is quite constant. Some of the organisms enter tissues and establish focal infections. Because of effective powers of resistance, defense, and repair, the majority are insusceptible. They are able to suppress the invading parasites without developing signs or symptoms of infection. The healing is so excellent that the residual pulmonary lesions are either undemonstrable postmortem or are too restricted to have hampered respiration. The lesions rarely, if ever, contain living bacilli.

Four grades of susceptibility occur among the minority who develop the disease. (1) The least susceptible recover sooner or later, however treated or maltreated. Healing is sound. Although the lesions in the lung are demonstrable intra vitam and postmortem, they are too restricted to hamper respiration materially. The residual lesions seldom contain living organisms. A proportion of these individuals acquire insusceptibility which is often lasting. (2) Those of moderate susceptibility will recover if properly treated, but only after longer periods of disability. The healing is good, but the greater extent of the residual lesions reduces pulmonary elasticity enough to impair respiration and curtail physical activity. Such residual lesions often contain living organisms. Some of these patients acquire increased resistance that may even approach insusceptibility, but it is likely to be transient. (3) Those of immoderate susceptibility cannot recover completely. Appropriate therapy enables them to retard, perhaps arrest, the progress of their disease after prolonged periods of rather complete disability. Respiration is so restricted by cicatrization of lung and pleura that physical

[1] Read before the American Surgical Association, May 12, 1927.

capacity is decidedly limited. The residual lesions contain living organisms quite constantly. Some recover sufficiently to enter gainful occupations without endangering their associates. Some develop decreased susceptibility, but this improvement is apt to be evanescent. (4) The progress of disease in those of extreme susceptibility can be barely retarded. On the contrary, unhygienic modes of living transform lesser grades of insusceptibility into susceptibility and intensify the degrees of susceptibility. Similarly, delayed, inappropriate, or prematurely discontinued treatment sacrifices opportunities for recovery or for arrest or retardation of the progress of the disease.

Prophylaxis is realized through hygienic modes of living that augment and conserve the powers of resistance, defense, and repair, thereby increasing insusceptibility and decreasing susceptibility. The effect upon lungs is to develop and to maintain high normal vital capacity. Treatment employs hygienic and other measures to reduce susceptibility. When effective it promotes healing of involved portions of lung with the least amount of scar and protects the uninvolved portions. The effect upon the lung is to restore and to maintain as high vital capacity as the residual cicatrices permit. Thus there is a desirable element of prevention in treatment. The earlier treatment is instituted, the larger the element of protection, the more promptly improvement is attained, the less the duration of immediate disability, the degree of ultimate disability, and the liability to reinfection or to recrudescence of previous infection.

Vital capacity, the largest volume of air that can be expired after full inspiration, is commensurate with the efficacy of the function of external respiration. External respiration, which is the basic function of the living, is produced by the combined activities of the breathing apparatus and of the blood-forming and blood-delivering structures that compose the circulatory apparatus. External respiration determines individual competence or the capacity to develop energy in excess of the amount required to support inactive existence. The degree of competence determines the capacity to combat disease. Consequently, none of the essentials in the treatment of intrathoracic diseases can be neglected if the measures employed keep vital capacity as high as feasible during the aggressive stage of the process and return it to normal during the regressive stage.[2] Hence it is necessary merely to recognize the untoward influences that reduce vital capacity in order to find the measures that will assist patients to combat those influences and simultaneously to discover when and how the measures should be utilized.

Normal vital capacity is possible as long as the breathing unit is intact, *i.e.*, pleuropulmonary elasticity is unimpaired, intrapleural negative pressures are unaltered, and movements of the thoracic parietes, particularly the diaphragm, are unrestricted *provided* the circulatory unit is uninjured so that

[2] The Significance of Vital Capacity in Intrathoracic Therapy. Archives of Surgery, 1925, vol. x, p. 471. The Significance of Vital Capacity in Intrathoracic Therapy. Archives of Surgery, 1926, vol. xii, p. 257.

suitable volumes of good blood are delivered under appropriate pressures through the pulmonary and bronchial arteries.

The nature of injuries inflicted by tuberculosis and by treatment that impairs the functions of the structures constituting the breathing and circulatory apparatuses, explanation of the effects of the injuries, and an outline of the means to modify or to avoid them will be considered in reference to (A) the breathing unit (pleuropulmonary elasticity, intrapleural pressures, movements of parietes) and (B) the circulatory unit (formation and delivery of blood through pulmonary and bronchial arteries).

A. BREATHING UNIT

Pleuropulmonary elasticity is reduced by (1) lesions of the parenchyma, (2) thickening of the visceral pleura and adhesions of the visceral to parietal pleura, and (3) protracted collapse and compression of the lung that cause permanent contraction.

(1) Lesions of the parenchyma consist of the reactions of the divers tissue cells to the action of irritants emanating from tubercle bacilli and of cellular and non-cellular elements derived from blood. The characteristics of the least unfavorable lesions are a more active proliferation of cells other than connective tissue, active hyperæmia, and eventual healing with minimal fibrosis. More unfavorable lesions, though they be the best attainable, are developed when there is a less active proliferation of the epithelial and endothelial cells, and a progressive fibrosis is accompanied or provoked by hyphæmia instead of hyperæmia.

Lung parenchyma possesses extraordinarily high power of resistance and repair. This native power differs insignificantly among individuals save as it is vitiated by emphysema, cicatrices, anæmia, which includes subnormalities in corpuscles and plasma, and by passive congestion, each of which, it should be noted, impairs external respiration and reduces vital capacity. Repeated deposition of more or less virulent tubercle bacilli upon epithelial surfaces of the lung is inevitable, and some infection is certain. The nature of the resultant lesions is determined very largely by the quality and quantity of blood delivered to the lung. Wherefore the healing of lesions can be promoted in three ways: primarily, by improving the quality of blood in circulation and increasing the unit volume of blood delivered to affected lung; secondarily, by so altering intrathoracic tension that the natural contraction of fibrous tissue can collapse intrapulmonary cavities or that reëxpansion of lung can obliterate intrapleural cavities; and, thirdly, if these are inadequate, by destroying such structures as prevent the healing of menacing and otherwise irreparable lesions.

All patients benefit by having the quality of blood improved and the unit volume delivered to involved lung increased. Those having moderately advanced lesions require the additional assistance provided by lesser alterations of intrathoracic tension, and those harboring advanced lesions need greater alterations in tension and perhaps the destruction of tissue.

(2) Visceral pleura is thickened, and adherent pleuritis is provoked by irritants extending to its under surface from lesions of the subjacent parenchyma or delivered upon its outer surface by effusions. Parenchymal lesions have been discussed. Surface irritants come from pleuritic effusions, from pneumothorax, be it spontaneous or induced, and affect both visceral and parietal reflexions of the pleura. Acute pleuritis subsides after the formation of adhesions.[3] The sooner inflamed pleural surfaces, separated by effusions or air, are reapposed and maintained in contact, the more rapidly inflammation subsides, the less the thickening, and the greater the likelihood of restoration of a pleural cavity. The powers of resistance and repair of pleuræ depend upon the quality and quantity of blood they receive, the greater power being supplied by the visceral reflexion.

Prevention and relief of acute pleuritis are attainable by improving the quality of blood in circulation and increasing the volume of blood delivered through the bronchial arteries which supply the visceral pleura in man, by restricting the excursions of the lung during acute phases of inflammation so as to facilitate formation of adhesions, and, if the pleural reflexions are separated by air or fluid, by reapposing them gradually by repeated or continuous aspiration. After the chronic stage of inflammation is established, excursions of parietes and of lung should be slowly increased by appropriate exercises in order to stretch adhesions and gradually disrupt them because this is one means to restore the integrity of serous membranes. When lung has become so retracted after prolonged collapse or compression that reëxpansion is impossible, some form of thoracoplasty must be employed to reappose the pleural surfaces.[4]

(3) Collapse and compression of lung are the more advanced stages of deflation. Deflation develops as intrapleural negative pressures are reduced but not abolished. Collapse obtains when negative pressures are neutralized and the lung is under atmospheric pressure. Compression increases as pressures exceed that of an atmosphere. Respiratory excursions of lung in deflation are restricted; in collapse, are quiet; and in compression, are entirely inhibited. The volume of collapsed lung is the resultant of contractile force (elastic recoil) and of expansile forces (the expansion produced by the blood-pressure in the pulmonary artery, the six-fold greater systemic pressure in the bronchial artery, and by the positive intrabronchial air pressure of forced expiration). The volume of compressed lung is less than that of collapsed lung because positive pressure is added to the contraction pro-

[3] Wounds of the Thorax from The Oxford Surgery, 1921.

[4] The advocates of induced pneumothorax recognize the certainty of provoking pleuritis by the introduction of a foreign substance, the need to aspirate the pleuritic effusions that occur with some frequency after pneumothorax has been established, the greater efficacy of this procedure when intrapleural negative pressures are reduced but not abolished, and the impossibility of maintaining constantly the desired level of reduction in negative pressures. Enthusiasm for a means of proved virtue has blinded the majority to its vices which can be eliminated by using a method that accentuates natural responses without introducing a morbid condition.

duced by elastic recoil and expansile forces are no greater. Fibrosis present in diseased lung increases elastic recoil and tends further to diminish the volume of diseased lung in both collapse and compression. Fixation of even normal lung in collapse or compression leads eventually to such firm contraction of its component structures as to prevent reinflation if artificial pneumothorax is employed. Correction of collapse and compression is achieved by timely aspiration of air or fluid, which should be withdrawn or allowed to escape so gradually as to avoid cardiac disturbances. When permanent collapse is to be established by thoracoplasty, it should be produced in stages to limit the amount of readjustment required at any one time and to determine when every benefit has been attained so that needless mutilation can be avoided. Compression is caused by pressure exceeding an atmosphere. It is not produced by ordinary thoracoplastic operations. It should not be occasioned by extraordinary procedures because it provokes ischæmia and increases cardiac labor.

Intrapleural Negative Pressure.—Negative pressure arises from the elastic recoil of the lung acting in a vacuum when the pleural reflexions are not adherent. It fluctuates with grades of inflation and of deflation and is higher as inspiration increases and lower as expiration increases. Inspiration is produced by elevation of sternum and elevation and rotation of ribs, by widening of intercostal spaces, and by contraction of the diaphragm. Unforced expiration is caused by elastic recoil of lung and by a similarly elastic recoil of the parietes resulting from relaxation of muscles that induce inspiration reënforced by contraction of intercostal muscles. Fluctuations in negative pressure and in inflation and deflation of the lung are both reduced when movements of the parietes are restricted. It will be shown that the largest volume of blood is delivered to each unit volume of lung when the fluctuations in negative pressure and the excursions of the lung are restricted. Intrapleural negative pressure disappears with pleuritic adhesions. Inflation is effected by direct transmission of expansile force from parietes to lung. Unforced deflation is caused by elastic recoil of lung and parietes and by contraction of intercostal muscles. Pleuritic adhesions limit inflation because the pleural surfaces do not glide and parietal movements are restricted. Vital capacity is correspondingly reduced.

Restriction of pulmonary excursions to those just above and just below the mean is desirable in the aggressive stage of the disease. It can be accomplished by reducing intrapleural negative pressure either by the introduction of air that assures pleuritis or by the restriction of parietal mobility that increases protection against pleuritis. The latter means are equally applicable when pleuritic adhesions or sound judgment prevent the use of induced pneumothorax. Abolition of negative pressure is undesirable; creation of positive pressure is unwarranted.

Movement of the Parietes.—Excursion of the lung through all grades of inflation and deflation, and therefore vital capacity, is more dependent upon motions of the parietes than upon any other factor. Limitation of parietal

mobility is necessary during the aggressive stage of the disease because of its similar influence upon the range of pulmonary excursions. Restricted excursion reduces the rate of removal of toxic products, favors repairs mechanically, and vouchsafes the maximal blood supply that promotes sound healing. Parietal mobility is restricted automatically if there be acute pleural irritation. This is a natural defense response which develops spontaneously or can be provoked in man and other animals. Parietal mobility is usually insufficiently restricted in pulmonary tuberculosis because in earlier stages the pleura is not irritated and in later stages the pleural cavity is frequently obliterated. Motion of parietes can be limited to conform with propitious natural degrees of restriction by blocking nerve trunks transmitting motor impulses to the diaphragm. Paralysis and consequent atony of the diaphragm permit positive intra-abdominal pressure to displace it upward. Movements of the balance of the parietes of that side are automatically reduced, or, even if there be adhesions, lung volume is reduced, pulmonary excursions are limited to those just above and below the mean, and the physical conditions are established that nature has proved most effective in promoting pleuropulmonary resistance, defense, and repair. There is another and equally noteworthy aspect. Persistance of parietal immobility beyond recovery is quite as undesirable as is its absence during illness. Vital capacity is lowered, and the individual's competence is diminished. Reduction in vital capacity is equivalent to the limitation of motion of the diaphragm which is more influential than the costal parietes upon pulmonary excursions. Consequently, as long as recovery is a possibility paralysis of the diaphragm should be induced by temporary blocking of the phrenic nerve (phrenemphraxis) which can be made permanent later if necessary by exeresis or phrenisectomy that should be used primarily only when restoration of function is undesirable. Similarly, costectomies should not be performed until the need of this means of aiding healing is established and then without delay. Thoracoplasty can but alter intrathoracic tension. The utmost accomplishment is to place an entire lung in collapse. Patients who need thoracoplasty are quite certain to have developed adhesive pleuritis at least over the most affected portion of their lung. Wide resection of ribs overlying the lung most involved promises the largest benefits and are the ribs to be excised first. The number of ribs removed should be as few as needed to promote healing because every additional rib removed imposes a reduction in vital capacity, greater mutilation, and worse than needless immediate operative risks.

B. CIRCULATORY UNIT—FORMATION AND DELIVERY OF BLOOD

Blood Formation.—Continued production of each of the corpuscles and of each of the constituents of blood plasma in numbers and in amounts suited to age, sex, habits, and environment is essential to preserve health, to afford protection against pathogenic agencies, and to permit recovery from disease when that protection has been inadequate. Blood corpuscles and plasma are formed in part in the lymphatic and the balance in the extra-

lymphatic portions of the circulatory apparatus. The cellular and non-cellular elements produced by extralymphatic structures are the more efficacious in affording protection and defense against parasites that provide acute maladies, in affording resistance against the initial action of parasites that provoke chronic diseases and against the subsequent increased action of such parasites as introduce acute exacerbations in the course of chronic ailments, and in promoting the earlier phases of repair following more abrupt injuries to tissues. The cellular and non-cellular elements produced by the lymphatic structures are more efficacious in providing defense against parasites that provoke chronic affections subsequent to their initial action or to action introducing acute exacerbations, in producing immunity against certain organisms that initially provoke acute maladies, *e.g.*, scarlet fever, and in promoting the later phases of repair after abrupt injuries to tissues or virtually all phases of repair when the injuries are inflicted gradually. Protection and defense provided by blood elements produced by neither the lymphatic nor the extralymphatic structures are efficacious without the other, and similarly the corpuscles alone or the plasma constituents alone are inefficacious. The numbers, proportions, and physical characteristics indicate the functional capacity of each of the corpuscles in circulation and also the functional capacity of each of the five groups of hæmocytoblasts that form the corpuscles. If hæmocytoblasts are competent, the number and physical status of their corresponding daughter cells are normal or above normal. If they are incompetent, the number of daughter cells is below normal or abnormally increased, and they are altered in size and in structure. The responses of hæmocytoblasts to irritants disseminated through the circulation from local lesions will be favorable or unfavorable according as the cells are competent or incompetent. Incompetence of mother cells is either reparable and recovery is possible or irreparable and recovery is impossible. Incompetence can be remedied by reducing intoxication, improving nutrition, and, when necessary, supplying corpuscles through transfusion to allow the mother cells to rest and recuperate. The evil effects of irremediable incompetence of hæmocytoblasts can be minimized by repeated transfusion that supply enough cells to reduce deficits. This is urgently needed when oxygen-carrying power is curtailed by erythrocytopænia and hæmoglobinæmia and when there are deficits in other corpuscles particularly needed in defense, such as lymphocytes and platelets, else arrest or retardation of the progress of the disease is unattainable. All constituents of the plasma are necessary, but the ones most significant in disease are those providing ingesta—water, salts, and nutrition, the specific and non-specific antibodies are as far as can be estimated at present commensurate sites and that tend to neutralize or inactivate noxious products of parasites or of tissue degeneration provoked by parasites. Deficits in specific and non-specific antibodies are so far as can be estimated at present commensurate with the degree and nature of acceleration of sedimentation rates though these deficits are not the sole causes of the increased rapidity of sedimentation. Incompetence of the cells elaborating antibodies are responsible for the deficits

in these substances, and, like corresponding incompetence of the mother cells of the divers blood corpuscles, the incompetence is reparable or irreparable. Moreover, the remedies are similar. Rest, fresh air, sunshine, and suitable diets are needed. Deficits in water, salts, and glucose that cannot be supplied through the digestive apparatus can be given intravenously and at the same time noxious substances in the blood are diluted and their elimination is facilitated. Oxygen-carrying power of the blood is as a rule materially reduced in the very patients who are deficient in their elaboration of antibodies. The oxygen-carrying power is raised and the antibody deficits are somewhat corrected by transfusion if donors are chosen who have unusually high antibody content in their blood, that is, blood from individuals of natural or recently acquired insusceptibility. Recovery is impossible if the antibody content remains low. Repeated transfusions are necessary and blood unmodified by anticoagulants must be employed because available anticoagulants impair or destroy antibodies.

Insusceptibility, as well as the divers degrees of susceptibility to tuberculosis, is traceable, primarily, to the quality of blood in circulation, and, secondarily, to the volume of blood delivered through the bronchial and pulmonary arteries. Provision of means to treat patients requires recognition (1) of the nature and sources of deficits in corpuscles and in plasma elements which permit infection to become established, of the favorable and unfavorable responses developed by the various blood-forming structures according as patients are able or unable to control the subsequent evolution of disease, and (2) of the natural mechanism whereby delivery of blood is effected and modified spontaneously.

The numbers and characteristics of the corpuscles in patients at or soon after onset are usually but little altered save in acute pneumonic processes and when gross abnormalities of blood have been the predisposing agency. Limited neutrophilia, lymphocytosis, and increase in transitionals indicate favorable responses and vice versa. On the other hand, increased rates of sedimentation are quite constant. Evidence to date suggests that distortion of sedimentation is due largely to deficits in specific and non-specific antibodies which are caused by incompetence in lymphatic structures.[5]

As the evolution of the disease progresses, patients who effect favorable healing of their pulmonary lesions likewise develop favorable responses in their cellular and non-cellular blood constituents. Moreover patients so

[5] Individuals inherit lymphatic tissue of different degrees of competence. More pronounced degrees of incompetence are noted in status lymphaticus. Functional capacity of lymphoid tissue differs with sexes and fluctuates with age, season, modes of living, and can be dissipated by overwork, by prolonged exposure to X-ray and radium, to certain coal-tar derivatives, and by lymphotoxic diseases, notably influenza. Normal fluctuations in the capacity of blood-forming elements in the lymphatic section of the circulatory apparatus and reduction in the competence of structures inherently less robust caused by usual and unusual stresses of life explain why some diseases, *e.g.*, tuberculosis and cancer, occur more frequently at certain ages and why by exception they develop at ages commonly exempt.

treated as to improve the quality of blood commonly effect better healing. The contrary is equally true. Patients whose pulmonary lesions are progressive are simultaneously progressing toward cachexia in which both cellular and non-cellular blood elements are distorted and most deficient. Patients in whom deterioration of their blood cannot be remedied are unable to arrest the progress of their pulmonary lesions.

Recovery is concomitant with or perhaps preceded by a reëstablishment of a normal quality and volume of blood. Permanent insusceptibility results when the blood-forming organs, especially the lymphoid portions, instead of being subcompetent, have acquired a lasting competence. Transient insusceptibility or a state of evanescent increased resistance occurs when competence is not maintained or when it is but partially and temporarily realized. The status of the blood may be likened to the horse and the nature and extent of the pulmonary lesions to the cart. The roadway is rough, and the grade rises more or less unevenly. A weak horse cannot pull even a partially loaded cart uphill, and, if the load be too heavy, a strong horse will be exhausted. We must avoid placing the cart before the horse and over-rating the significance of either horse or cart. Means to strengthen the horse, *i.e.*, to improve the quality of blood, have been outlined. Means to reduce the load, *i.e.*, to decrease peripheral resistance to blood flow and to diminish the production and retard the absorption of noxious substances, are quite as helpful if they be provided without injuring the horse. The tendency is to concentrate attention upon the cart and to overlook the horse because a majority of patients are overburdened, some at onset, the balance when they appeal for help.

Delivery of Blood Through the Pulmonary and Bronchial Arteries.—The volume of blood delivered is determined by myocardial power, by the quality and quantity of blood in circulation, and by the peripheral resistance to the flow through the arteries.

Blood flow in the lesser circulation is controlled hydrodynamically. The blood delivered is to be aërated (external respiration) and does not supply lung structure with its bulk of nourishment. Peripheral resistance fluctuates with inflation and deflation. It is least at the mean between full inflation and full deflation. The larger vessels and the capillaries in the walls of air sacs are in this position neither the more elongated, as they are in inflation, nor the more tortuous, as they are in deflation. The unit volume of blood delivered to a unit volume of lung is not only greatest but also is delivered with the least cardiac effort. Fixation of a diseased lung in the mean position, although it would minimize both cardiac labor and the rate of absorption of noxious substances from lesions and hasten healing, is fortunately as impossible as it is undesirable. Non-use restricts the amount of blood delivered through the bronchial arteries which nourishes lung and visceral pleura and causes atrophy and consequent lessened resistance of pleuropulmonary structures. Resistance, defense, and repair are highest and are secured with the greatest possible economy when pulmonary excursions are restricted to those just above and below the mean. Such restriction, as stated above, is a natural

defense reaction which can be imitated to a nicety by induced paralysis of the diaphragm.

Blood flow through the bronchial arteries, though modified to a degree by the physical conditions of inflation and deflation, is further influenced by vasomotor impulses. Amounts of blood delivered to lung structures and to visceral pleura are increased with activity and decreased with inactivity. They are likewise increased with the more active defense responses and diminished if these responses are of the less active, fibrosing type. Whatever be the nature of the process in the lung, defense and repair will be fostered by richer blood supplies, which will be provided most propitiously when pulmonary excursions are restricted but not abolished and with the least cardiac labor.

Thus far only the volume of blood delivered to an affected lung has been considered. The total volume of blood delivered through the lesser and greater circuits must be the same if life is to continue. Blood forced into pulmonary arteries takes paths of least resistance. If intracapillary resistance be increased by parenchymal lesions, by collapse or compression, a part of the blood that normally would pass through these vessels is diverted into adjacent capillaries offering less resistance. These capillaries are overfilled, and, because of the air-cell-capillary mechanism described by Dunham, the overfilling produces compensatory functional emphysema. This is nature's automatic device to maintain external respiration at a high level with a margin of safety in addition. The cost is an increment in cardiac labor.

The practical significance of these responses warrants emphasis. Normal folk have more than enough lung to aërate all the blood their hearts can deliver while their physical activities are uttermost, and more than thrice as much lung as is required to aërate the blood delivered while at rest. If the volume of lung structure destroyed by disease or inactivated by treatment exceeds the excess volume that provides the usual margin of safety, the limit of activities is correspondingly curtailed. Also any activity that requires pulmonary expansion above that of rest imposes an abnormally heavy burden upon the heart because an excess of functional emphysema must be provided in order to effect aëration. Paralysis of one side of the diaphragm reduces the upper limit of exertion approximately one-third if the heart is strong. If, in addition, the volume of lung is further reduced by costectomies, the handicap is increased. Each change in lung volume, be it an increase or a decrease, is accompanied by alterations in the distribution of blood within the lesser circuit and corresponding differences in heart work. Consequently, alterations in lung volume produced by aspiration of air or of pleuritic exudates, by the injection of air, or by costectomies should be made gradually. No functioning lung and no inactivated lung that can be aided to function again should be sacrificed except as a last resort.

II. Reasons why non-operative treatment alone or operative treatment alone must fail to satisfy therapeutic requirements and why those require-

ments will be fulfilled when proper non-operative and operative measures are promptly utilized in suitable combinations.

Experience has demonstrated that degrees of susceptibility of patients suffering from the disease in its incipient stage cannot be measured with dependable accuracy. The physical and mental states *at the time* of examination always can be estimated, but not the reserve powers which provide the margin of safety requisite to recovery. Two types of patients are illustrative of this fact. Some, apparently quite robust and likely to recover promptly, grow worse after longer or shorter intervals, however good be the initial care. Such individuals develop their maximum defense early, and subsequently the structures producing essential portions of that defense undergo progressive deterioration which at best can only be retarded. Others, obviously weakened and presumably incapable of developing adequate defense, need relatively little assistance to achieve recovery by virtue of the abundance of their reserve powers.

The proportions of patients who recover despite treatment and of those who need little help to achieve recovery are large enough to have obscured the significant issues. Attention has been centred rather upon successes, which are less creditable than is supposed, than upon failures and the need to explain and to remedy them. According to precedent, early treatment is expectant until after patients have demonstrated their incapacity to recover, and only then, when it may be and frequently is too late, attempts are made to provide additional assistance.

Non-operative and operative measures that will benefit each patient without being harmful to any are not employed from onset. Rest, particularly enforced mental inactivity, is often overdone; fresh air is provided through open windows instead of by living and sleeping outdoors; direct exposure to sunshine is denied or is overdone; diets are atrocious; good food, should it be purchased, is vitiated by mediocre cooks and less than mediocre serving; fresh fruits are deficient in quality and in quantity; sufficient amounts of good water are not provided; phrenemphraxis, or the less wholesome artificial pneumothorax, is delayed; transfusion of unmodified blood from well-selected donors is not even considered.

There is a large measure of grim humor in the insistent exhortations to send patients to sanatoria immediately a diagnosis is reasonably certain and then, through prejudice and procrastination, to sacrifice the invaluable element of prevention by failure to provide *all* means to expedite improvement and thereby curtail the duration of immediate and the extent of ultimate disabilities. The sublime touch of irony is to attribute unfavorable results entirely to individuals' lack of stamina or to their failure to submit gracefully to routine discipline.

The conditions attendant upon the treatment of patients in more advanced stages of the disease are not quite the same. They are naturally or have been forced into the more susceptible class. Their margins of safety are correspondingly narrowed. They no longer may be assisted by operations to

avoid permanent disability; they must be assisted to recover despite crippling incapacity. The possibility of providing the needed assistance is reduced. Procrastination is again the most common mistake. It can be explained but not justified. Measures have not been employed so as to offer a reasonable certainty of benefit without imposing unreasonable hazards. Patients are subjected to operation who are beyond help in the hope of some miraculous achievement.

Thoracoplastic operations are performed to immobilize and compress lung and thus to "cure" tuberculosis. Operators argue as to whether the upper or lower ribs should be resected first, how small a segment of rib it is necessary to excise, whether a given number of centimetres of eleven ribs should be removed in one or more stages, and whether the anæsthetic should be local, general, or combined. The nature, extent, and location of lesions and the propriety of preserving the function of uninvolved lung apparently do not enter into calculation. Internists are relied upon to decide which patients are suited for operation and which are not. Inability to improve under pacifistic measures demonstrated by having observed continued progress of the disease over considerable periods is the one accepted indication for operation. Preparation of patients so as to reduce risks and to limit the extent of operation is given scant, if any, consideration. Proof of the superiority of measures advocated is submitted in the form of statistics. Figures are given that show the percentages of those that are "cured," improved, unimproved, and succumbed, but no mention is made of the basic factors, the capacity of patients to make, to deliver, and to aërate blood before, during and after operation.

Operations can but aid in improving the quality of blood, in increasing the unit volume of blood delivered to the affected lung, in reducing cardiac labor, in restricting the excursions of diseased lung, in altering intrathoracic tension so as to facilitate healing, and in eliminating irreparably diseased tissue. These adjuncts in treatment will be the more efficacious the earlier they are employed if they be employed in proper sequence, but they can be fully efficacious only if the other measures, *e.g.*, diet, amounts of rest and exercise, fresh air and sunshine, are suitable. Surgeons are held entirely responsible for the recovery of patients whatever be their condition when referred for operation. Surgeons have the right to insist that non-operative care be of the best before and after operation, that opportunities for operative assistance be offered to patients early, and that those subjected to operation be sufficiently robust not only to withstand the immediate stress but also later to profit by the intervention. They are obligated to devise and adapt operations that will promote the welfare of each individual and to deny possible benefits to none lest an unfavorable outcome impair the impressiveness of statistics. Clinicians, if there be reasonable doubt, cannot as yet determine whether or not usefulness of life may be increased and prolonged save by trying. Fatalities soon after operation need occur infrequently; indeed, life should

be lengthened so regularly that the benefits conferred can be measured by increment in usefulness.

III. How operations can be performed to (a) improve the quality of blood, (b) increase the quantity delivered to affected lung with least cardiac labor, (c) alter intrathoracic tension so as to retard absorption and promote healing, and (d) eliminate irreparable lesions without the addition of undue hazards.

(a) *Quality of Blood.*—In the early stages blood deficits are quite constant in the plasma, whereas the responses of the hæmatocytoblasts are usually favorable. If improvement is not prompt and progressive with rest, diet, fresh air, sunshine, and phrenemphraxis, transfusions of unmodified blood from donors known to be insusceptible should be employed. No other means are as certain. Should this assistance fail to produce improvement, the prognosis is quite hopeless.

The blood deficits in the later stages include both cellular and non-cellular constituents and are the early phases of cachexia. The quality can be often improved, and the volume in circulation can be raised by the intravenous administration of salt and glucose solutions before, during, and after operation, sometimes supplementary to transfusions, sometimes instead of them. Thus some patients can be prepared for operation who would otherwise be unable to withstand the added stress; some whose blood pressures waver during operation can be stabilized; and those whose pressures fall after operation can be resuscitated. Patients so assisted are not only enabled to survive operations, but also are the more certain to derive greater benefits from them.

The helpfulness of transfusions of unmodified blood, particularly when repeated, are unrecognized by those who have used improperly selected donors, have added anticoagulants to the blood, or have employed transfusions, usually singly, too late, or not at all.

Two dangers are avoidable. Too large amounts of blood or blood introduced too rapidly will cause acute dilatation of the right heart. If the blood is introduced too slowly, particularly in hot weather, clotting is likely. The embolism need not be immediate and can be fatal several days later. If there be doubt, the amount of blood that can be given safely may be determined before transfusion by testing tolerance with intravenous glucose injections. Patients, dehydrated and starved from gastro-intestinal malfunctions, especially by vomiting, are greatly benefited when given salt and glucose intravenously.

In order to determine what should be done to assist patients, it is only necessary to remember that serious blood deficits in cells or plasma preclude recovery and prohibit operation. Some may be corrected in one way, others in different ways. The basic facts are established. Patients' general condition and their lesions become more favorable as their blood improves. Conversely, if the healing of lesions is facilitated by operation, the blood and general health are bettered. In other words, some operations, *i.e.*, transfusions and intravenous injections, improve the blood directly. Other opera-

tions that retard absorption of noxious products by limiting pulmonary excursions or reduce the irritants disseminated by facilitating healing improve the blood indirectly because the blood-forming units are thereby relieved of slight but constant injuries.

(b) *Quantity of Blood.*—Restriction in parietal mobility and in the intrapleural negative pressure needed to diminish the volume of lung and to limit its excursions so that the delivery of blood shall be most advantageous for repair can be attained in accordance with natural responses by paralyzing the diaphragm. Paralysis of the diaphragm decreases vital capacity and restricts competence of the individual.

Blocking the nerve trunks conducting motor impulses to the diaphragm may be temporary or permanent. Temporary blocking is indicated as a part of treatment when the disease is incipient or moderately advanced as a means to check hemorrhages and as an introduction to more radical operations if later the recovery of function of the diaphragm will be advantageous. Permanent blocking is expedient in some of the few patients whose diaphragms cannot be paralyzed by measures that produce temporary blocking, in the patients whose improvement ceases as the diaphragm is reactivated following temporary blocking, when healing of existing lesions would impose handicaps as great or greater than diaphragmatic paralysis, and as a preparation for extensive costectomies.

A diaphragm can be paralyzed for from two to four months by crushing the branches of the phrenic nerve more or less severely.[6] Adequate exposure is attained through a transverse incision, one and a half inches long, extending mesially from the outer margin of the sternomastoid muscle in a skin crease just above the clavicle. Fibres of the sternomastoid are separated in the outer third of the muscle and retracted. The deep fascia is divided along the lower border of the omohyoid, and this muscle is dislocated laterally. Sometimes the scalenus anticus lies lateral to the deep jugular vein, and this vessel need not be disturbed. Sometimes the scalenus anticus lies behind the vein which is loosened along its lateral margin and retracted mesially. The fat overlying the scalenus anticus is separated mainly by blunt dissection so as to avoid injuring the transverse cervical artery. Retraction of this fat permits search for the phrenic nerve trunks. They are fused in one bundle in about three out of five persons, which lies on the anterior surface of the scalenus anticus in accordance with the classical description. There may be two or three branches similarly placed or the branch or branches may lie along or even behind the lateral or mesial border of the muscle. Rarely one or more branches perforate the sternomastoid. Not infrequently accessory branches

[6] Transient paralysis of the diaphragm, lasting three or four days, can be caused by injecting the motor branches of the phrenic with 1 per cent. cocaine. This is useful before thoracotomy and to relieve exceptionally severe hiccoughing. Paralysis of longer duration can be provoked with the injection of alcohol of appropriate strength, but is too dangerous. Not only is wound healing impaired, but there is also likelihood of provoking an intense neuritis in the trunks of the brachial plexus.

accompany the nerve to the subclavius muscle, descend into the chest lateral to the usual course of the phrenic, and join the main trunk of the phrenic at a lower level. Accessory branches arise from the lower three cervical and first thoracic nerves and by exception from the twelfth cranial. Exceptionally the diaphragm receives considerable motor innervation from the twelfth thoracic nerve.

When the phrenic consists of one trunk it contains both motor and sensory branches. When there is more than one trunk, though motor and sensory branches are usually mixed, they may be separated. Consequently, any one branch may be transmitting only motor or only sensory impulses or mainly motor or mainly sensory impulses.

Paralysis of the diaphragm produced by nerve blocking or phrenemphraxis is most effective when complete, and when complete a paradox appears; the paralyzed side ascends during inspiration. The simplest way to determine when relaxation is attained is to perform operations with the patient upon a fluoroscopic table. The motion of the diaphragm is observed; then the phrenic nerve is exposed. If one large trunk is encountered, it is held gently in a clamp; the fluoroscope is used; and the clamp is closed abruptly. A sudden contraction of the diaphragm occurs. If all the motor nerves have been blocked, motion ceases; the diaphragm rises, and a paradox appears at once or after some hours. Otherwise, following the first contraction, there is incomplete relaxation, and some contraction occurs with deep inspiration. It is then necessary to discover accessory branches, to repeat fluoroscopic observations, and so continue until immobilization is attained. In ten patients out of twenty-five the main trunk, when found, is smaller than usual. Accessory branches are sought, first lateral, then mesial to the scalenus anticus. Crushing and fluoroscopy are continued until immobilization is produced. Careful dissection and a little experience make it possible to succeed in causing a transient paralysis in all but a few patients, possibly two per cent.

Permanent paralysis can be induced by extensive crushing of phrenic nerve trunks, by resecting portions of the trunks (phrenisectomy) and by dividing the main trunk and extracting the distal portion from the chest (exeresis).

Exeresis is the method of choice. It is only necessary to locate the main branch of the phrenic as its withdrawal will tear out accessory branches. Failure to cause complete paralysis is very rare and occurs when the diaphragm receives a considerable part of its motor innervation from the twelfth thoracic nerve or possibly if an accessory branch fails to fuse with the main trunk of the phrenic. It is unwise to use much force in extraction because of the danger of disrupting adhesions and provoking hemorrhage. Under such conditions extraction is carried to the limit of safety and the trunk excised at its lower level of exposure. This is the one indication for phrenisectomy. During extraction of the distal segment of the nerve the thoracic duct may be torn close to its termination. Patients to be subjected

to exeresis on the left side should drink milk slowly before operation. Then laceration of the duct cannot be overlooked and the leaking duct is easily found and ligated, a harmless procedure. Phrenicotomy and severe and extensive crushing of the phrenic nerve are not employed because they do not assure permanence of paralysis. All operations on the phrenic nerve are performed under local anæsthesia.

(c) *Alteration of Intrathoracic Tension.*—The first step is to induce temporary or permanent paralysis of the diaphragm and then wait a reasonable time to determine whether further intervention is necessary and to permit the intrapulmonary circulation to become readjusted. Patients needing additional assistance are of two types, those having rather diffuse involvement of the lung and those with the main lesions in the upper lobes. There is quite certain to be adhesive pleuritis over the involved lung so that the greatest effects of costectomy will be within subjacent lung. When the involvement is so general that collapse of the entire lung seems to be required, removal of ribs may well begin below. Delorme showed that the effects of rib resection were largest if the resection extended from behind the angle posteriorly and was carried forward to include the costal cartilages. We believe it expedient to follow Delorme's advice. An incision is made along the lateral margin of the erector spinæ muscles from the seventh rib to the eleventh and extended forward along the eleventh interspace. The twelfth and eleventh ribs are removed entirely and as much of the tenth, ninth, and eighth as can be reached, seldom more unless the patient's condition is unusually good. It is always safer to do just too little at any stage. The next step is to make an incision over the costal cartilages and to remove the parts of the ribs left at the first session and the costal cartilages from the tenth upward. When feasible the costal margin is exposed; the diaphragm, parietal pleura, and pericardium are pushed backward with blunt dissection. Then, instead of subperiosteal and subperichondrial resection, cartilages, ribs, and intercostal muscles are removed even back to include the field of original operation. The alteration of intrathoracic tension is as great as can be produced; regeneration of ribs and cartilages is prevented; the operation is easier and shorter; the distress is no more. Should additional resections be needed, they follow in alternating stages, back and front, until all excisable ribs and cartilages have been removed. Intervals between operations should be no longer than necessary for recuperation and to determine if further intervention is indicated. Some patients regenerate bone so promptly that if there be avoidable delay, the new bone nullifies the effects of previous and subsequent operations.

Resection of ribs begins above when the lesions are in the upper lobe. The object is to provide the relaxation needed to permit these lesions, which include numerous cavities, to heal. Wide resections are indicated but limited to the immediately overlying and subjacent ribs so as to preserve the function of the lower lobes. If the alteration of tension thus provided is insufficient to promote healing, a serious problem arises.

(d) *Elimination of Irreparable Lesions without Undue Hazards.*—Is it wiser to continue to resect ribs and inactivate good lung or should the lesions in the upper lobe be destroyed with a cautery as employed by Graham? Wide resection has been efficacious, but the reduction in vital capacity is too great. If partial and complete lobectomy with cautery is feasible, we believe that destruction is the better method. No patient has been willing to submit to this operation.

Anæsthesia is suited to the patient and to the operation. No one method can be employed as a routine. Nitrous oxide and ethylene are preferable to ether. Local anæsthesia is often imperative. Combined local and general anæsthesia has disadvantages that almost balance its manifest advantages.

Removal of pleuritic effusions and pneumothorax is desirable as a rule and frequently imperative. Tuberculous effusions can be removed advantageously, as Bowditch showed in 1850, by repeated aspirations. It is now possible to employ continuous one-way drainage. Harm occurs when the removal is too rapid or when the entrance of air is not prevented. The pleural surfaces are gradually reapposed, become adherent, and further effusion is impossible. If the lung cannot be reinflated, the parietal pleura is to be depressed to the visceral by appropriate costectomies in conjunction with aspiration or drainage. Air in the pleural cavity should be aspirated gradually unless immediate withdrawal be necessary to save life. If the diaphragm continues to move after the effusion or the pneumothorax develops, phrenemphraxis should be employed as well as aspiration.

Observations of the effects of operations upon patients at the Muirdale Sanitarium and Columbia Hospital since the measures described have been employed will be summarized to illustrate both advantages and disadvantages.

Transfusions.—Vincent paraffined tubes have been used. Robust donors are selected who are over thirty years old or who have recently recovered from active tuberculosis. The latter are preferable. Grouping and cross-checking of the bloods of donors and recipients are carefully done. Repeated transfusions of patients whose capacity to make blood is dissipated have given only transient benefits. Patients still able to make blood have shown progressive improvement after transfusion. A few, apparently hopeless, have been enabled to withstand operations that seem to have introduced recovery. One man, exsanguinated from repeated hemorrhages, was resuscitated with transfusion, and his bleeding ceased after phrenemphraxis. One woman was resuscitated after operation when death was imminent. She developed acute pneumonia later in the sound lung and another transfusion was followed with a rapid convalescence. Acute cardiac dilatation was caused in one man but did not prove fatal. One woman who was failing rapidly improved remarkably following three transfusions. On the fourth day after the last transfusion she suddenly became cyanotic and dyspnœic. She lived four days. Necropsy disclosed an embolus almost completely plugging the pulmonary artery in her sound lung. Glucose and salt in hypertonic solutions have proved their value and should have been used more often.

Paralysis of the Diaphragm.—Temporary blocking has been induced ninety times in patients whose disease is classified as incipient, moderately advanced, and advanced. Alcohol, 60 per cent., was injected in three. Crushing was used in the others. The transverse cervical artery was torn in one; the subclavian vein was lacerated in one; both recovered. One patient developed a spontaneous pneumothorax on the opposite side and died because a diagnosis was not made. This occurred before the present staff was appointed. One man has since developed a pneumothorax following costectomy. It was recognized promptly and relieved by aspiration. No other complication has been encountered. It was difficult at first to gauge the amount of crushing required. The paralysis is permanent in three patients and has been too brief in a few others. Recent results seem to be dependable. Operative and post-operative discomforts are slight; healing is smooth; scars are not prominent; and there is no deformity.

Permanent paralysis has been induced forty-two times, exeresis thirty-one, and phrenisectomy eleven. Once exeresis failed to produce paralysis. Twice the thoracic duct was lacerated and ligated at once without noticeable effect. The disease of all patients was advanced.

An exact estimate of the effects of induced paralysis of the diaphragm is impossible because it was only a *part* of treatment. Except the one patient sacrificed by failure to recognize pneumothorax, none was injured. Some received no benefit. Some improved after operation who had failed to improve before and the treatment was otherwise the same over a period of years. Some improved until the diaphragm regained its activity and then began to fail, thus proving that paralysis had been beneficial. A few patients in whom paralysis was induced preparatory to costectomy proceeded toward recovery without further intervention. In others the preliminary paralysis was a factor in limiting the number of ribs it was necessary to resect. Preliminary paralysis appeared to reduce the hazards of subsequent thoracoplasty. Induced palsy alone or with transfusion has stopped hemorrhage from pulmonary and bronchial arteries and does not predispose to hemorrhage although one patient died of hemorrhage subsequent to phrenemphraxis. Paralysis of the diaphragm is as effective or more effective than induced pneumothorax and is applicable when there are pleural adhesions. It imitates natural defence responses and does not add one morbid state to help another. No refilling is necessary. The total discomforts are less.

We believe phrenemphraxis is warranted as soon as a diagnosis is established. The diaphragm will be functioning again by the time an incipient lesion can be healed and the patient's general health is stabilized. It will hasten as well as facilitate recovery. Temporary or permanent paralysis should be induced in all but the fatally affected patients in whom the disease has passed the incipient stage, as it promotes repair, obviates the need for further intervention, or reduces the extent and risks of more radical operations if they are required. It is a dependable means to control hemorrhage and to reduce pain.

Twelve patients have been subjected to twenty-nine rib resections that removed more or less completely four to twelve ribs. All were prepared with preliminary paralysis of the diaphragm, some with transfusions. None has died. Two were benefited but temporarily. Two are apparently healed, and their blood is normal. The others are improving and may require no further operation.

Radical resection of ribs, perhaps including the intercostal muscles, can be done virtually without danger if the operations are adapted to the requirements of individuals who have been suitably prepared and procrastination is eliminated. Many patients thus assisted who would otherwise be confined to sanitoria will be enabled to recover sufficiently to lead useful and productive lives without endangering or annoying their associates.

CONCLUSIONS

Improvement of methods of treatment is needed if each patient is to be given full opportunities for undelayed recovery from pleuropulmonary tuberculosis or for prompt arrest or retardation of the progress of the disease.

The basic obligation of treatment, which is to promote healing of pleuropulmonary lesions with the least cicatrization, is attainable by improving the quality and increasing the quantity of blood delivered to affected lungs and restricting their excursions, by altering intrathoracic tension, and by destroying irreparably diseased structures.

This obligation can be fulfilled whether the disease be incipient or advanced by combining non-operative measures (rest, diet, fresh air, sunshine, and drugs) with operative measures (transfusions of unmodified blood, intravenous administration of salt and glucose solutions, induced palsy of the diaphragm, resection of parietes, and partial or complete lobectomy with cautery).

Operative adjuncts to the non-operative methods of treatment, applicable whether the disease be incipient or in more advanced phases, are not only available, but also will fulfill therapeutic requirements if utilized in proper sequence, without adding hazards save the infrequent accidents of minor surgery.

Progressive improvement in the treatment of pleuropulmonary tuberculosis is assured and will be the more rapid if the non-operative and operative measures now in use are modified and new measures are developed so as to coöperate even more effectively with the natural responses which provide resistance, defense, and repair.

THE TREATMENT OF SUCH CASES OF CHRONIC SUPPURATIVE BRONCHIECTASIS AS ARE LIMITED TO ONE LOBE OF THE LUNG*

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The term suppurative bronchiectasis, at the present time, is used rather loosely to include not only true suppurative bronchiectasis in which the disease is limited to the bronchial tree, but also those conditions in which there is a varying amount of infection in the parenchyma of the lung, associated with dilatations of that part of the bronchial tree. This latter pathology, we believe to be much more common than the former in which the disease exists only in the bronchial tree. The amount of infection in the lobe may vary from a comparatively small area about the branches of the bronchus to one that includes the entire lobe. Probably a more correct term is chronic bronchopulmonary infection with bronchial dilatations.

It seems to the Thoracic Clinic at the Massachusetts General Hospital, that all methods of treating this disease other than its radical removal by some surgical procedure, are merely palliative and will not cure this condition, with possibly extraordinarily rare exceptions.

Medical treatment may be dismissed by saying that it will never cure this condition, although if the patient can devote his days to taking care of his health, spending his winters in a warm dry climate, and using postural drainage, it may be that he will live a long and fairly comfortable life.

Bronchoscopy will not cure this disease, but if the patient is willing to be bronchoscoped at regular intervals, there is no question but what his condition will be improved, in that the septic symptoms will largely subside and the amount of sputum raised will be diminished. It seems to us that the greatest benefit from bronchoscopy is obtained from aspiration of the pus from the bronchial tree, by the dilatation of any stricture or strictures of the bronchus and by the removal of any granulation tissue that is tending to obstruct the bronchus. We do not feel that irrigation of the bronchial tree or the injection of medicated oils is of any therapeutic value. The early cases of bronchiectasis which are caused by the lodgement of a foreign body in a bronchus and which are promptly cured by its removal, are not included in this discussion.

A third possible method of treatment is artificial pneumothorax. Here, again, we do not believe that any cure can be brought about by its use, with possibly very rare exceptions. On the other hand, if the lung is not adherent to the costal pleura, so that it can be completely collapsed, the general condition of the patient will be improved and the amount of sputum will be much diminished. But when the lung is allowed to expand, the symptoms

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gradually return and it is found that the disease has not been cured. In many instances in which artificial pneumothorax is kept up for a long time, fluid will appear in the pleural cavity, which will cause this form of treatment to be abandoned, and it is not uncommon for this fluid to become infected, or, as in our experience in a few cases, during the treatment adhesions have been torn, opening the infected area in the lung, resulting in a virulent empyema. The condition then becomes more serious, as to the bronchiectasis there is added an acute empyema.

In an extensive research of the literature for the last twenty-four years, the impression is gained that there have been many failures, many partial improvements and there is an absence of any considerable number of actual cures. Those that are reported cured seem to us to fall more into the classification of lung abscess than into that of bronchiectasis.

Surgical operations for this condition are two-fold. The palliative ones by which no absolute cure should be expected (except possibly in extremely rare instances) and the radical ones by which a cure may be expected in a large percentage of the cases that survive the procedure.

There is no reason to suppose that drainage of the diseased area will produce a cure. However, it is quite justifiable to drain a large dilatation of a bronchus or a large abscess of the lung for temporary relief. This operation merely changes the direction of the drainage, and where the patient has been raising quantities of pus by coughing, following the operation large quantities come through the drainage tube and will continue to do so as long as there is an open sinus.

There is a certain amount of difference of opinion as to the value of graded thoracoplasty. When the disease is situated in more than one lobe of the lung, it seems to be the best operative procedure. But in dealing with the disease where it is limited to one lobe, our experience has led us to believe that it should be undertaken merely as a palliative. The general condition, following this operation, may be much improved and the amount of sputum temporarily or permanently greatly reduced, but it does not entirely disappear and the patient is not absolutely cured.

It would be a presumption for me to discuss Graham's cautery lobectomy, as our experience with this has been a very limited one. But in certain instances, when a limited amount of lung tissue is to be removed, as in cases of chronic abscess of the lung, situated near the periphery, which, although they have been drained, show little if any signs of being cured and have small hemorrhages, it seems to us to be the ideal procedure.

Amputation of a lobe of the lung inside the pleural cavity has been accompanied by a very high mortality. In fact the mortality has been so high in our hands at the Massachusetts General Hospital that the operation has been abandoned for the present, at least. Out of 6 cases operated upon, only 1 left the hospital alive. Some of the deaths were caused by unexpected accidents, as, for example, a sudden fatal secondary hemorrhage on the sixteenth day after the operation, and the development of a brain abscess in another

case six weeks following operation when the side operated upon had done very well and after the patient had reached the stage of being up in a wheel-chair.

About a year and a half ago it occurred to us that it might be possible to do a lobectomy in an entirely different way, and the technic about to be described was employed in 5 cases, in all of which the disease was situated in a lower lobe. Under gas-oxygen and ethylene anæsthesia the pleural cavity is opened and the diseased lobe of the lung examined to determine the extent of the process and also the amount of adhesions about the lobe. This seems to us important, as, if the adhesions are very firm and extensive, it may be unwise to attempt a lobectomy. But if lobectomy is decided upon, sections of enough ribs are removed so that the diseased part of the lobe may be delivered from the pleural cavity after adhesions and the pulmonary ligament are divided. The lung is firmly sutured to the muscles of the chest wall by chromic catgut and heavy linen thread, taking very deep stitches into the lung tissue. One large gauze sponge is placed beneath the lobe to aid in holding it, and a No. 20 French catheter is placed to the root of the lung, kept shut off, and the wound closed as tightly as possible. By means of this catheter the large quantity of bloody serum that collects in the pleural cavity for a few days may be removed without allowing air to enter. Needless to say, when the operation is completed the amount of lung protruding from the wound seems small, it being possibly as large as an orange, but there is a good deal more lung tissue outside the pleural cavity that is hidden by the thickness of the chest wall. After this operation there has been surprisingly little shock and the picture is entirely different from that following the usual procedure, as we have seen it. Nature may then be allowed to complete the operation, as in about ten days the lobe has become necrotic. A dry gangrene is at first established, then gradually there is a profuse foul discharge and eventually, in about four to five weeks, this whole area sloughs off, leaving a clean healthy granulating stump deep in the pleural cavity with bronchial fistulæ in it. During this process of sloughing and discharging, the cough gradually diminishes to finally cease in the successful cases. The wound is lightly packed with gauze each day until it closes, which in the 2 completely cured cases took roughly three to four months from the time of operation. It was unnecessary for the patients to remain in the hospital for more than six to eight weeks. In the 2 cases that made complete recoveries, the bronchial fistulæ gradually closed without anything being done to them.

In one case of upper lobe disease, not included in this series, in which the operation was attempted, after the adhesions had been divided, the lobe was so small that it could not be delivered.

It may be that preceding this procedure a preliminary graded thoracoplasty should be done. Our reasons for not doing this were the fear that it might cause the formation of such firm adhesions that it would be impossible to free the lobe and also that the pressure on the lobe would cause it to become so small that it could not be delivered. We believe that whatever vital

capacity exists in the diseased lobe is promptly cut off by the operation, and that there is no danger of mediastinal fluttering in doing the operation in one stage. The empty space in the pleural cavity is, we think, gradually obliterated by the ascent of the diaphragm, the inflation of the upper lobe and the collapsing of the chest wall.

Apropos of this procedure, it was interesting to find in Stephen Paget's *Surgery of the Chest,* published in 1896, a report of 2 cases of hernia of a lobe of the lung following penetrating wounds of the chest wall in which there was no attempt to replace the lobe. The first case quoted by Paget was reported in 1499 by Rolandus and briefly is as follows:

"Called to a citizen of Bologna on the sixth day after his wound, I found a portion of the lung issuing between two ribs; the afflux of the spirits and the humors had determined such a swelling of the part that it was not possible to reduce it. The compression exercised by the ribs retained its nutriment from it, and it was so mortified that worms had developed in it. The most skilful chirurgeons of Bologna, judging death to be inevitable, had abandoned him. But I, yielding to his prayers and those of his parents and friends, made an incision through the skin, the breadth of my little finger-nail away from the wound, all round it. Then, with a cutting instrument I removed all the portion of the lung level with the incision. By the grace of God the wound cicatrized and recovery took place."

Paget also quotes a case of Tulpius in 1674 of "A man who while drunk received a penetrating wound below the left nipple, but was too drunk to heed it. The next day he found a protruding portion of the lung of three fingers' breadth. He now took a two days' journey to Amsterdam with the lung still hanging out unheeded and undressed. Tulpius ligatured it and cut it off with scissors. The patient healed quickly and had no further trouble save a cough at times."

It would seem from a comparison of these 2 cases with the 5 reported here, that we have unwittingly come upon a simple technic employed by nature four hundred years ago.

Of the 5 cases (full details of which will be published with this paper), No. I, a boy, aged eighteen years, and No. III, a man, aged forty-eight years, made complete recoveries, in that they are entirely healed, have no cough or sputum and have returned to their normal occupations. Case I left the hospital at the end of eight weeks and was entirely healed three months after operation. Case III stayed in the hospital six weeks and was entirely healed three and a half months after operation. Case II, a boy, aged nineteen years, has improved, as the cough and sputum are much less than before operation, he still has a small thoracic fistula, after a period of a year and three months, but has been well enough this winter to drive a truck every day. In Case IV, a boy, aged nine years, the side operated upon did as well as the others had done, but he died on the tenth day following operation, having developed pneumonia on the other side. Case V, a man, aged twenty-three years, was operated upon only six weeks ago and is making a very good convalescence.

It is well realized that it would be absurd to draw any conclusions from these 5 cases, but it seems fair to make the following statements:

1. That it is possible to perform a lobectomy by this method.

2. That in our hands this operation has been followed by less shock than any other technic.

3. That 2 of the 5 cases have been cured and have returned to their normal occupations.

4. That the operative procedure can be completed in one stage without excessive risk.

CASE I.—A. P. D., Massachusetts General Hospital, 272,322. A boy, aged eighteen years, entered the hospital, October 1, 1925. His chief complaint was that he raised a large amount of foul sputum each day.

Present Illness.—Two years previous to entering the hospital, without any known preceding illness, the patient began to cough and raise sputum which soon acquired a foul odor and nauseating taste. The cough and sputum raised gradually increased in severity and in amount, until for the past six months he has been having three or four paroxysms of coughing each twenty-four hours, during which he raises about a pint of foul purulent sputum. Has lost no weight and has no other complaint or symptoms. Family history and past history irrelevant.

Physical examination shows a well-developed boy, but somewhat thin. His general appearance, however, is a fairly healthy one. There is considerable clubbing of fingers and toes. In the left back there is some dulness and a few scattered râles; otherwise nothing abnormal found. Temperature varies from 97° to 99° F., pulse 70 to 80, respiration 20. Urine, negative. Examination of blood shows: White blood-cells, 12,000; red blood-cells, 5,000,000; hæmoglobin, 85 per cent. Sputum 10 to 12½ ounces daily, foul and green in color. Short chain streptococci, both intra- and extracellular. Occasional leptothrix. Many influence bacilli.

Operation, October 8, 1925, under gas-oxygen anæsthesia. A long section of the eighth rib removed. Pleural cavity opened, lower lobe explored and found to be adherent to the diaphragm and upper lobe. There was a thickened, hard, dark area occupying the lower third of the lobe. Long sections of sixth and seventh ribs excised. After the lobe had been freed from adhesions, it was brought out to the chest wall and sutured there (using the technic already described).

Good convalescence. Eight days after operation the necrotic part of lung burned off with actual cautery. Severe hemorrhage, but this was controlled by packing with gauze. The convalescence following this was very smooth and patient was discharged to Out-patient Department eight weeks after first operation. Wound gradually closed in and healed. On April 8, 1926, patient reported at Clinic entirely healed, no cough and able to resume his normal occupation.

CASE II.—J. J. D., Massachusetts General Hospital, 274,418. A boy, aged nineteen years, entered the hospital February 2, 1926. His chief complaint was that he had been coughing and raising foul sputum for eight months.

Present Illness.—One year ago the patient had influenza with pleurisy and was in bed six weeks. He made a complete recovery and returned to work. Eight months ago had a tonsillectomy performed under ether, which was followed almost immediately by a non-productive cough, and two weeks later had a foul breath and began to raise foul-smelling and tasting sputum. Six months ago began having paroxysms of coughing, during which he raised large amounts of purulent sputum. For many weeks has had two to three chills and nightsweats per week. Has lost 12 pounds in weight, but feels well and vigorous except for coughing. Family history and past history irrelevant.

Physical examination shows a well-developed and nourished boy. Right chest is

diminished in size and excursion. There is increased fremitus, decreased breath sounds and slight dulness over the right lower back. Some râles are heard at the apex. There is slight clubbing of fingers and toes. Temperature varies from 97° to 97.5° F., pulse 70 to 90, respirations 20 to 25, urine negative. Examination of blood shows: White blood-cells, 13,800; red blood-cells, 4,600,000; hæmoglobin, 75 per cent. Sputum 3 to 7 ounces daily, occasionally blood-tinged and foul. Examination shows pneumococci, streptococci, staphylococci, influenza bacilli, no tubercle bacilli.

Operation February 8, 1926. Gas and oxygen anæsthesia. A long section of seventh rib removed. Pleural cavity opened. Examination of lower lobe showed it to be adherent to diaphragm and there was a large, hard, dark area in it about as large as a lemon. Long sections of sixth and eighth ribs removed. Lower lobe freed from adhesions and brought out to the chest wall and sutured there.

Convalescence good. Discharged to out-patient department six weeks after operation, with a persistent sinus and bronchial fistulæ and some cough and expectoration.

Patient was last seen on November 16, 1926. At this time his general condition was good, but he still had a small thoracic fistula. Patient stated that whenever he caught cold, he coughed and raised some purulent sputum, but that when he did not have a cold, there was very little sputum and very little discharge from the fistula.

Case III.—A. A. V., Phillips House, Massachusetts General Hospital, April 16, 1926. A man, aged forty-eight years. A year and five months previous to entering the hospital had all his teeth extracted under ether. He states that in about ten days he began to have a cough and pain in the left lower part of chest. Soon after this began raising considerable foul-tasting sputum. Has been unable to do any work and has devoted himself to trying to regain his health by rest and medical treatment. He states that his cough is worse at night than in the daytime and that during each twenty-four hours he raises nearly a pint of pus, which at times is very foul smelling.

Physical Examination.—Thick-set man, prominent abdomen, short neck, muscles well developed. Nothing abnormal found in heart or right lung and the only changes from normal in the left lung are occasional râles and dulness below the angle of the scapula. Temperature normal, pulse 70 to 80.

Examination of sputum shows many leucocytes and occasional squamous cells, a few blood-cells, no tubercle bacilli, many influenza bacilli, and pneumococci, streptococci and staphylococci, also some large bacilli.

X-ray examination shows a definite process in the left lower lobe, which involves the bronchi and peribronchial tissues. The lower portion of the shadow is quite mottled and is suggestive of several cavities, but there are no fluid levels to be demonstrated.

Patient returned to his home for about three weeks, in order to attend to some business matters and then returned for bronchoscopic examination, which showed a large amount of pus coming from the left lower lobe bronchus. This was injected with lipiodol and X-ray taken following this, showed several dense shadows in the left lower lobe, which were interpreted to be several abscess cavities, some being larger than others.

Operation, June 3. Started under local anæsthesia and completed under gas and oxygen. Sections of the ninth and tenth ribs were removed, the pleural cavity opened and the lower lobe of lung explored. At one small area this was adherent to the costal pleura, but otherwise was free from adhesions. A hard, firm area, about the size of a lemon, occupying the lower part of the lobe, was easily palpated.

Section of the eighth rib was then removed and the diseased part of the lung delivered onto the chest wall and sutured there. Gauze was placed around this part of the lung and a catheter placed in pleural cavity. The wound was then closed as tightly as possible.

The patient was returned to bed in excellent condition. For two days large amount of bloody serum was aspirated from the catheter at frequent intervals. For two days temperature rose each afternoon to 100° F., but after this did not go above 99° during his entire convalescence. At the end of two weeks the lung had become necrotic and

was slowly sloughing away. The patient's cough was gradually improving and the amount of sputum diminishing. At the end of four weeks the lung had sloughed off, leaving a healthy granulating stump and the cough had entirely disappeared. At the end of six weeks, the patient was discharged from the hospital with a wound that was rapidly filling in and required only one gauze sponge for packing. He returned to his home in the western part of the state of Massachusetts and was there taken care of by his local physician. He returned to me on October 17, 1926, at which time his wound was entirely healed, he had no cough, felt very well and his only complaint was some numbness along the costal margin. He has since returned to his normal occupation.

Case IV.—R. B., Massachusetts General Hospital, 278,053. A boy, aged nine years, entered the hospital, August 12, 1926. His chief complaint was cough with abundant purulent sputum.

Present Illness.—Ten months ago aspirated a pistachio nut. A week later had high fever, cough and chills, and was in bed for six weeks. The acute symptoms subsided, and were followed by chronic cough, foul breath and foul purulent sputum. He was said to have had "pneumonia" two months ago followed by exacerbation of symptoms. He has had severe paroxysms of coughing with evacuation of large quantities of pus, and then fall in temperature. The sputum has been occasionally blood-streaked. He has lost 5 pounds in year. The family history and past history irrelevant.

Physical Examination.—Thin, poorly nourished boy. Skin dry. Left chest diminished in size and excursion. In the left back below the angle of the scapular, there is dulness and increased fremitus. Many râles are heard on this side and a few posteriorly on the other side. Temperature varies from normal to 101°, occasionally up to 105° F. Pulse, 90 to 150. Respirations, 20 to 50. Urine negative. Examination of blood shows: White blood-cells, 9700 to 15,000; red blood-cells, 4,500,000; hæmoglobin, 75 per cent. Smear, moderate achromia. Wassermann, negative. Sputum, 1 to 4 ounces daily. Many pneumonia streptococci, influenza bacilli, and no tubercle bacilli. Bronchoscopy showed left primary bronchus filled with muco-pus, which was aspirated and an apparent abscess cavity observed. Lipiodol injected.

Operation, October 1, 1926, under ethylene. Long sections of the fifth, sixth and eighth ribs were removed. The lower lobe was thick, hard and contained many small abscesses. The lobe was mobilized and brought out on to chest wall and sutured there. Transfused after operation. His condition was fair. On the third day after operation signs of pneumonia developed in right mid-chest. On the seventh day he was transfused again. There were definite signs of pneumonia in the right side. The patient died on the tenth day following operation.

Case V.—N. P., a young man, aged twenty-three years, entered the Massachusetts General Hospital, March 29, 1927. His chief complaint was cough with abundant very foul sputum.

Present Illness.—Four years ago he had a right-sided pneumonia followed by empyema, which was operated on twice by rib resection in a hospital in another city. Drainage was kept up for five months, when the wound closed. Soon after this he began to cough and raise pus. Two years ago he worked for eight months, but as his cough and sputum gradually increased, he gave up his work. In February, 1927, went to a sanitarium where no tubercle bacilli or other evidence of tuberculosis was found. Patient states that for several months before entering the hospital, he was raising about two cups of very foul-smelling pus each twenty-four hours, which had never contained any blood.

Physical Examination.—Well-developed and nourished man, but rather pale, with marked clubbing of the fingers and toes. The sinuses not remarkable. There is a perforation of the nasal septum. The record states: "Horrible breath that announces his presence." There is dulness in the right lower back, with diminished breath sounds and diminished tactile fremitus. There are a few râles in this region, otherwise the lungs are negative and the heart is negative.

X-ray Summary.—Old thoracotomy wounds in ribs of lower right chest. The findings are those of a pathological process in the right lower lobe, and multiple areas of diminished density, which suggest cavitation and incomplete expansion of the lung. Appearance suggests bronchiectasis, otherwise the lungs are clear.

The urine is negative. Blood examination shows white blood-cells 16,000, red blood-cells 3,500,000, hæmoglobin 55 per cent, blood-pressure 110/80.

Operation, April 8, 1927, under ethylene and gas oxygen. Sections of seventh, eighth and ninth ribs were removed. Very firm adhesions were found between the lung and pleura. The pleura was found considerably thickened. The lower lobe was found to be small and hard; it was freed from adhesions to the pleura, upper lobe and mediastinum. Deep stitches with chromic catgut were taken close to the root of the lung and gently tied; these were then brought out through the muscles and tied.

One large gauze was placed beneath the lung to the bottom of the pleural cavity. A No. 20 French catheter was placed to the root of the lung and three small gauzes also placed about the delivered portion of the lung. Wound closed as tightly as possible.

Following operation patient was transfused.

Good convalescence. For three and a half weeks his temperature ran daily up to 101 or 102° F. Troubled with hemorrhoids and irritated rectum with some diarrhœa. This gradually cleared up and temperature became normal at end of four weeks. At this time lobe had sloughed off leaving healthy stump in pleural cavity with fistulæ in it. There was very little cough and sputum. There is no odor to the breath or sputum and there has been none since one week after operation.

SOME SURGICAL PROBLEMS ATTENDING THE OPERATION OF EXTRAPLEURAL THORACOPLASTY

By Arthur A. Law, M.D.

of Minneapolis, Minn.

To obtain a cure in all cases of unilateral pulmonary tuberculosis the primary object, irrespective of the procedure used, is to put the diseased lung at rest. This physiological rest can only be accomplished by collapsing the organ. In 80 per cent. of one-sided tuberculous cases this collapse can be successfully accomplished by artificial pneumothorax. In the other 20 per cent. because of the adhesions between the parietal and visceral pleuræ complete collapse of the lung is prevented. It is in this 20 per cent. of cases that the so-called "Wilms-Sauerbruch" operation of paravertebral extrapleural thoracoplasty offers the only possibility of that collapse. In a study of our series of 91 operations of extrapleural thoracoplasties performed upon 51 patients during the last five years, we have been impressed by the fact that complete collapse has failed of accomplishment following the operation in 8 per cent. of the cases, this failure making necessary supplementary and different surgical procedures. Sauerbruch's observations parallel these of our own. He states that in 14 per cent. of his cases there was failure of collapse and the necessity of further surgery. We noted in 3 of the earlier thoracoplasty cases where we had failed to thoroughly and completely remove the ribs close to the vertebral transverse processes, after the new ribs had regenerated from the periosteum and had fused and immobilized the collapsed thoracic cage, in the costovertebral angle left between the rib stumps and the vertebra, there was a definite area of uncollapsed lung which persisted and which defeated the object of the primary operation. In these cases we were forced to do a third-stage operation, to reinvade the old operative field and with rongeurs removed the stumps of the ribs close to the spine, also enough of the regenerated ribs to permit of complete collapse of the hæmothorax and obliteration of the dangerous angle. Again in 4 cases after both stages of thoracoplasty operation had been done we found that apiceal cavities persisted despite the collapse of the thoracic cage. The fibrosis of the peripheral walls of the cavity held it patent, with resultant persistence of expectoration and the constant menace of extension of disease to the well lung. This is the type of case where the Touffier "apioclysis" procedure used to be exploited, where resection of the ribs in front and stripping of the parietal pleura from the chest wall was followed by transplantation of a pedicled muscle flap, a sterile gauze sponge, paraffin, or an autogenous transplant of fat. Whichever method was used the endeavor was to collapse the cavity walls. This pneumoclysis has a relatively high mortality and its employment has crystalized into its being used, according to Lilienthal, "where only the

* Read before the American Surgical Association, May 12, 1927.

compression of that part of the lung is desired" or where further surgery is contra-indicated. In our 3 cases we did a third-stage operation (parasternal) through an incision like the preliminary incision of Rodman's breast operation, removing the costal cartilages and several centimetres of the first, second, third and in one instance the fourth ribs. This procedure which following the two primary stage thoracoplasty operations gave excellent collapse of the thorax with ultimate collapse of the cavity. In one case we removed the anterior wall of the apiceal cavity with a cautery blade and then treated the cavity with mercurochrome-220, gentian violet and nitrate of silver. A tuberculous fistula has persisted for eighteen months, the cavity is still patent —we contemplate a complete thoracoplasty to collapse and obliterate it. Sauerbruch and his assistants have exploited phrenocotomies as a preliminary to extrapleural thoracoplasty, paralyzing one side of the diaphragm and thereby lessening the lung capacity by from one-sixth to one-third. He believes that this operation alone is indicated in certain cases and in others is an index to the patient's resistance to surgery. In the rare cases of unilateral basal tuberculosis or where the patient is too ill to accept the immediate hazard of the larger thoracic procedure, or where after complete thoracoplasty the base of the lung fails to completely collapse, we have done the operation of phrenocotomy or, in the later cases, that of exeresis of the phrenic nerve. This latter operation is indicated because in 20 to 30 per cent. of the cases there is an accessory phrenic nerve which after resection of the main trunk of the nerve still helps to enervate the diaphragm. Avulsion of the nerve avulses as well the accessory branches and assures certain paralysis of the hæmodiaphragm. Experience has shown that it is only necessary to avulse from 10 to 12 centimetres of the phrenic nerve to destroy all accessory branches, yet frequently 30 centimetres have been avulsed. After thoracoplasty and these accessory operations, X-ray studies of the collapsed lung have been made after instillation of lipiodol. These studies have borne out the clinical observations that the collapsed lung is at rest and non-functioning. The bronchi usually are shown as collapsed and few if any of the lung markings are visible. Occasionally the remains of collapsed cavities are shown or a bronchiectatic dilatation noted at the base of the collapsed lung. While these unfortunate tuberculous patients who come to operation of thoracoplasty or its supplementary surgery are bad operative risks and face a primary operative mortality of 1.5 per cent. and a secondary mortality, within six weeks, of 12 per cent., yet we must consider that most of them are doomed to a tubercular death without operative relief; as Alexander has shown from a study of 1159 operated cases in America and abroad that 36.8 per cent. are cured and 24.4 per cent. are decidedly improved. Surely if 61.2 per cent. of tuberculous patients can be saved to usefulness the operation needs no further argument. If the estimated 30,000 cases suitable for this operation in America alone were given the benefit of surgery and 18,360 helpless invalids were restored to health, no further brief is needed to justify this type of surgery.

FURTHER EXPERIENCES WITH INTRA-THORACIC TUMORS*

By George J. Heuer, M.D.
of Cincinnati, Ohio

In June, 1923, I presented before this Society my experience with eight cases of intra-thoracic tumor, which had been subjected to operation. These cases included a sarcoma of the rib, a benign calcified intra-pleural cyst, a benign xanthoma, a benign chondro-myxoma arising from the costo-vertebral articulation, an aneurism of the descending aorta, mistaken for a tumor, and three circumscribed endotheliomas of the pleura. It was an especially favorable group from a surgical viewpoint and a radical removal was attempted in each instance. In six of the eight cases a radical extirpation of the tumor was accomplished; in two (aneurism and pleural endothelioma) was deemed impossible. One patient died following operation. Of the five cases which recovered after a radical removal of the tumor, four were living at the time of the report; one, seven years, one, four years; and two, two years. One died ten months after operation presumably from a recurrence.

Since the time of that report, I have records of 25 additional cases, making my series up to the present time, 33. The 25 cases include:

(a) Two cases of sarcoma of the bony chest wall.

(b) Eight tumors of the mediastinum, *i.e.:*

One teratoma.

Two malignant tumors, probably sarcoma or thymoma, one associated with pernicious anæmia.

Two benign tumors, the diagnosis made on the long history and X-ray picture.

Two mediastinal Hodgkin's disease confirmed by biopsy.

One posterior mediastinal abscess mistaken for tumor.

(c) Three diffuse endotheliomas of the pleura.

(d) Nine tumors of the lung, *i.e.:*

Three primary carcinomas of the lung—one also called an endothelioma.

Four primary sarcomas of the lung—two also called endotheliomas.

Two metastatic tumors in which the pulmonary symptoms were predominant.

(e) Two so-called hour-glass tumors involving the spine and thorax; one a neurofibroma.

(f) One apical chest tumor diagnosed a myxo-sarcoma.

Of these 25 cases only nine were subjected to operation. The nine included one chest wall tumor, one teratoma of the mediastinum, one apical tumor, one posterior mediastinal abscess, one hour-glass tumor and four malignant tumors of the lung. The remainder were either obviously so

* Read before the American Surgical Association, May 12, 1927.

advanced that surgical treatment was contra-indicated or refused operation. Two of the most favorable cases in the series—the two cases of circumscribed benign lesion of the mediastinum, absolutely refused operation because of their general satisfactory condition. In a number of the advanced cases deep X-ray therapy was tried with brilliant, if temporary, results in the cases of Hodgkin's disease, but with little benefit in the remainder.

Of the nine cases subjected to operation, in only three was a radical extirpation of the tumor in the accepted sense of the term possible. These three cases include the mediastinal teratoma, the apical tumor and the hour-glass tumor of the cord. The case of posterior mediastinal abscess is not included. Of the three cases in which radical removal of the tumor was possible all recovered from the operation; two are well for from one to four or more years, while one—the apical tumor—had a recurrence within a year, and subsequently died.

To fully review this series of 25 cases would take me far beyond my time. I can only comment upon some of the interesting features of different groups of cases and then refer in more detail to the three cases in which radical extirpation was possible.

Perhaps the first comment one would make who has read the literature and whose own experience is gradually, if slowly, increasing, is the need of a clearer understanding of the pathology of intra-thoracic tumors. When one attempts to assemble the cases of any group of intra-thoracic tumors, he finds it almost impossible because of the varied terminology and the uncertainty as to the nature of the tumors. Whether one should call a given pleural tumor an endothelioma, a carcinoma or a sarcoma is just one example of a confusion which exists in many groups of intra-thoracic new growths. No one observer can do much to clarify the situation, for the number of cases he sees is too small; and it would seem necessary if we are to advance in the understanding of intra-thoracic new growths that the combined efforts of many be devoted to the subject. We ourselves have experienced great difficulties in classifying our tumors; for no two of our pathologists agree about many of them. As in other fields of surgery, we must begin with a pathological understanding before we can greatly advance in the diagnosis and treatment of these tumors.

Of the chest wall tumors, one illustrated a common mistake made here as in tumors elsewhere. A colored man was admitted with a swelling over the lateral thoracic wall attached to the ribs. He had a four plus Wassermann and was admitted with a diagnosis of a syphilitic lesion. Under anti-syphilitic treatment the swelling seemed to diminish and the pain decreased. In spite of this I advised operation, which was refused. Subsequently he developed a symmetrical lesion on the opposite side. While anti-syphilitic treatment was being given, both tumors softened and the original one became fluctuant. When the patient finally consented to operation, a radical operation was impossible; but a local excision of one of the tumors proved it to be a sarcoma.

Of the mediastinal lesions perhaps three deserve mention. One, a teratoma of the mediastinum to be more fully described later, presented the complication of a widespread infection with multiple abscesses in the tumor, with a discharging sinus in the neck communicating with an abscess in the teratoma and with a chronic empyema communicating externally by a drainage tract and internally with the growth. In spite of all these complications, the teratoma was removed, the chronic empyema cured, the sinus of the neck healed and the patient discharged well.

A second case presented the unusual association of mediastinal tumor and pernicious anæmia. The case was admitted to the medical service where a diagnosis of pernicious anæmia was made because of perfectly characteristic clinical and blood findings. She was transferred to our heliotherapy ward for the treatment of pernicious anæmia by radiation. Because of her thoracic symptoms X-rays of the chest were made and disclosed a mediastinal tumor which lay too far posteriorly perhaps for a thymoma. The association between mediastinal tumor, particularly thymoma, and leukæmia has been observed by Friedlander and Foot and Fabian, but in my search of the literature I have not found an association with pernicious anæmia. Unfortunately the nature of the mediastinal tumor is not known.

The third case proved at operation to be a posterior mediastinal abscess arising from a small tuberculous focus in the body of a vertebra. It is included because it illustrates another mistake we have made in diagnosis. In the series reported in 1923 we included a case of aneurism of the descending aortic arch which we explored under the mistaken diagnosis of tumor. The case of mediastinal abscess presented all the symptoms and signs of a mediastinal new growth: pain, dyspnœa, difficulty in swallowing, cyanosis, engorgement of the vessels of the upper thorax and neck and a circumscribed spherical shadow in the X-ray plate. There was no evidence of a spinal lesion in the X-ray and no evidence of tuberculosis elsewhere. We made a diagnosis of benign posterior mediastinal tumor and at operation found an abscess. The patient subsequently died of pneumonia.

The three diffuse endotheliomas of the pleura were characteristic of this condition. One presented an enlargement of the entire half of the thorax with bulging of the intercostal spaces. All had thoracic pain, severe dyspnœa, cyanosis and bloody effusion; and X-rays showed an enormous thickening of the pleura. Two cases had previously been drained in the hope of relieving the dyspnœa and a piece of thickened pleura removed for diagnosis. It is well known that aspiration of the fluid largely fails to relieve the dyspnœa in these cases; and this was well illustrated in our experience. Deep X-ray therapy had no effect upon the progress of the condition.

Of the seven patients with primary malignant tumors of the lung, four presented themselves with the symptoms and signs of empyema or lung abscess. Two had outspoken physical and X-ray signs of empyema and in each, aspiration of the thorax yielded pus. The possibility of a pulmonary tumor was suspected in one of the two cases, was unsuspected in the second.

At operation for empyema the tumor was discovered and a fragment removed in each instance. One patient died in the hospital without further treatment. The other recovered from his empyema and was subsequently operated upon for pulmonary tumor by Doctor Reid. As complete a removal of a squamous-cell carcinoma of the lung as was possible led to a marked improvement in the patient's condition and this together with X-ray and radium therapy gave the patient over two years of comfortable existence.

Two of the four cases gave the symptoms and physical signs of lung abscess and X-ray studies did not serve to differentiate this condition and tumor. Both were subjected to operation for presumed lung abscess. In one, the presence of a malignant tumor (sarcoma) was immediately evident and because of the vascularity of the tumor no attempt was made to drain the abscess. The symptoms of abscess, however, markedly improved and the patient was subsequently given X-ray therapy with considerable temporary benefit. In the other case an area of induration in the lung was penetrated and the abscess cavity opened and drained without finding anything to suggest a malignant tumor. Indeed sections taken from tissue forming the abscess wall showed nothing but chronic inflammatory tissue. The patient recovered and was discharged as a case of cured pulmonary abscess. About a year later he presented himself with sarcoma nodules scattered all over his body. While we have no autopsy record to prove it, it would seem that the pulmonary condition was a suppurating sarcoma.

The so-called hour-glass tumors form a very interesting group. Including our own case, there are but seven or eight described in the literature. But from conversations with neuro surgeons they must be more common than the number in the literature would indicate. Cushing has kindly sent me the abstract of one case and Elsberg tells me he has seen several. The characteristics of these tumors are that, arising within the spinal canal and causing compression symptoms with reference to the cord, they grow through an intervertebral foramen and extend into the mediastinum where they may enlarge sufficiently to cause thoracic symptoms; or arising within the mediastinum grow through an intervertebral foramen and secondarily compress the cord. In the majority of cases reported, the symptoms of cord compression have been predominant but more or less definite thoracic symptoms have led to an X-ray of the thorax and the discovery of the thoracic tumor in five of the seven cases reported. The surgical approach has been by laminectomy in five out of seven cases and the tumor followed into the thorax. In the case operated upon by me the intrathoracic portion of the tumor was small and was not discovered before operation. It was easily removed after the resection of portions of two ribs. The patient recovered and his cord symptoms entirely disappeared. He is well over four years. The second case presented the usual picture of a cord tumor and for a long time was treated on the orthopædic service for paraplegia. When first seen by me the patient had definite thoracic symptoms and an X-ray showed a large intrathoracic tumor. Her general condition and the presence of pressure sloughs over her spine

precluded operation; and the diagnosis therefore is not verified. The cases of hour-glass tumor must be differentiated from primary intrathoracic tumors with metastases to the spine, a number of which have been reported in the literature; and in some of which the cord symptoms were the first and predominant symptoms.

Certain apical chest tumors form another interesting group. It is difficult to classify them otherwise than by their location; for they may pathologically be endotheliomas, sarcomas or other tumors; and may arise from the pleura, the subpleural tissues or the sheaths of the subclavian vessels. Clinically they may present the symptoms of pain in the shoulder, axilla and arm, muscular twitchings in the arm and hand, weakness and paralysis of the arm muscles and an associated sympathetic nerve disturbance indicated by ptosis, contracted pupil and enophthalmos. The condition was particularly emphasized by Pancoast of Philadelphia in 1924, who called attention to their similarity in symptoms to cord tumors. In two of the cases reported by him, a diagnosis of cord tumor was made and in one a laminectomy was done with negative findings. It is significant that pain in the shoulder, arm, or hand may be present for some time before the apical tumor is conspicuous in the X-ray plate and the correct diagnosis may be missed unless the condition is remembered. The case seen by me presented the usual symptoms of pain in the shoulder and arm but while evident ptosis was present, Horner's syndrome was not so evident as in some of the few other cases reported. The X-ray of the thorax showed a large tumor which was radically and apparently totally removed. The patient recovered but there was a rapid recurrence of the tumor from which he died. The three cases in which a radical removal of the tumor was possible may be recorded in more detail.

CASE I.—*Infected teratoma of the mediastinum. Chronic empyema. Discharging sinus of the neck. Removal of the teratoma. Recovery.*

A white woman, age thirty-nine, so far as she knows always previously healthy, developed a severe attack of acute tonsillitis early in December, 1921. About the middle of December she noticed a small, painful swelling at the root of the neck, just to the right of the suprasternal notch, and a dull pain in her right upper chest. There was no cough or expectoration. In January, 1922, the swelling in the neck was incised by her physician and some thick, cheesy material, containing hair, was evacuated. The fever and thoracic pain did not subside, however, and February 22, the patient was again operated upon. At this operation a rib or ribs were resected just to the right of the sternum; the pleura opened and pus obtained. At the same operation, a rib was resected rather low in the mid-axillary line and pus again obtained. Drainage tubes were inserted. The patient was ill in bed for eight months and lost 35 pounds in weight. The sinus to the right of the sternum healed, but the sinuses in the neck and the lateral thoracic wall continued to drain. She presented herself at the Cincinnati General Hospital, October 20, 1925. Physical examination showed an emaciated, somewhat septic woman, with a draining sinus in the neck and lateral thoracic wall, with clubbing of the fingers, dulness to the right of the sternum and impaired resonance over the lateral and postero-lateral aspects of the chest. X-ray examination showed a mediastinal shadow extending into the right thorax and a chronic empyema cavity. A close examination of the mediastinal shadow showed small denser areas suggesting bone, possibly teeth. In view of the history of the discharge of hair from the sinuses

in the neck and thoracic wall and the solidity of the X-ray shadow, a diagnosis of infected teratoma of the mediastinum was made. Injection of lipiodol into the neck and thoracic sinuses showed local collections within the tumor shadow which were interpreted as abscesses.

The surgical problem presented by this case appeared a difficult one. The presence of infection complicated matters greatly, for it promised to make more difficult the separation of the tumor from surrounding structures because of dense adhesions, and exposed the patient to the dangers of pericarditis, should the pericardium be opened, and to a widespread pleuritis. It seemed to us wise to attempt to limit the infection to the tumor or clear up the infection entirely if possible, before attempting its total removal. At the first stage of the operation, October 31, 1925, therefore, the costal cartilages, adjacent ribs and right lateral half of the sternum lying over the tumor, were resected. The upper pole of the tumor was freed and cut across opening up an abscess cavity the size of a walnut. This cavity communicated with the sinus of the neck. In sectioning the tumor, cartilage, bone and rudimentary teeth were encountered. The tumor was then freed along its right lateral border and posteriorly, in doing which another abscess as large or larger than the first, was opened. This was proven to communicate with the lateral thoracic sinus. The cavity was filled with drains which were brought out of the operative wound. Because of the patient's condition, the operation was terminated, and the wound partially closed. There followed a period of dakinization through the sinuses of the neck and thorax and operative wound. For a considerable period, there was a through-and-through communication between sinuses and wound; but subsequently after five months, April 19, 1926, communication ceased and both sinuses and wound completely healed. The chronic empyæmic cavity became obliterated. We were tempted to be content with this result, but the patient had meanwhile gained so much in weight and general well-being, that we decided to go on. At the second stage, the previous wound was re-opened and the tumor with great difficulty surrounded. It was so intimately fused with the great vessels and pericardium, that no line of cleavage was ever found. The tumor was therefore sliced off the vessels and pericardium, so that we undoubtedly left small fragments of tumor attached to them. In cutting through the tumor, a number of small abscesses were opened. There was little bleeding throughout the procedure. The wound was left partly open. The patient's convalescence was satisfactory, excepting for the development of a chondritis, necessitating two subsequent minor operations for the removal of infected cartilage. At the time of her discharge in March, 1927, the thoracic wound had not completely closed. There had been a gain of over 30 pounds in weight. A recent letter states she is remarkably well. The wound, however, is not yet completely healed.

CASE II.—*Hour-glass tumor (neuro-fibroma) of spine and chest. Symptoms of spinal cord tumor—mediastinal portion of tumor not recognized. Laminectomy. Removal of extradural tumor with its mediastinal extension. Recovery.*

A man, age thirty-eight, was admitted with the complaint of paralysis of the legs. Up to the age of twenty-eight, his health had been excellent. For ten years he was very nervous, with frequent twitching of the muscles of his arms and legs. His present illness began two and a half years ago, with numbness in the sole of the right foot. Three days after the onset, the left foot became numb. The anæsthesia gradually extended up the legs, until at the end of a month, it had reached the knees. He next noticed that his toes dropped and that he was unable to flex the ankles. His walking became uncertain. Within six months after the onset of his illness, he was totally paralyzed and anæsthetic from the level of the xyphoid downward. There has been incontinence of urine and fæces for two years.

Examination showed complete paralysis of both legs but with transient spasm or jerking, usually involving the flexors and extensors alternately. There was moderate spasticity of both legs. The knee jerks were hyperactive, but there was no ankle clonus. A positive Babinski was present on both sides. Sensory examination showed anæsthesia over the lower half of the body, extending upward to a level corresponding with the eighth dorsal vertebra behind and the xyphoid in front. X-ray of the spine and chest were negative; but it should be said that an intra-thoracic extension of a tumor was wholly unsuspected and no special X-ray studies other than a flat antero-posterior plate, were made, to determine it. A diagnosis of spinal cord tumor was made.

A laminectomy was performed and a large extradural tumor was found lying under the sixth dorsal lamina and to the left of the midline. It had eroded and largely destroyed the sixth dorsal lamina and had extended forward, eroding the body of the vertebra and enlarging the intervertebral foramen. A spinal nerve ran into the tumor and emerged from it; and as the tumor had no other connection, it was assumed that it arose from the nerve. As the tumor was followed forward, it became necessary to remove the articular ends of two ribs and the articular processes of the vertebræ. It became evident that the tumor extended into the mediastinum, pushing the left pleura forward. The pleura was not attached to the tumor which was eventually delivered intact. It was interesting to note the suction exerted upon the tumor by the thorax. As soon as traction upon the tumor was released, the tumor was sucked back into the thorax with surprising force.

The patient made an uninterrupted recovery. There was a prompt return of motion in the legs. Within six months, he was walking about. He has been well over four years.

The tumor was of the hour-glass shape and on section proved to be a neurofibroma or endothelioma.

Case III.—*Right apical tumor. Symptoms of pain in shoulder, radiating down the arm. Ptosis. Physical and X-ray evidence of apical tumor. Radical removal of tumor. Recovery. Recurrence.*

A man, aged thirty-one, was admitted to the Cincinnati General Hospital, September 21, 1925, complaining of pain in the right chest and shoulder, radiating down the arm. His previous health had been good. In June, 1925, he began to have pain in the right shoulder and right scapular region, radiating down his right arm. This came on periodically and gradually grew more intense. It has always been worse when lying down and is relieved by the upright position and by motion. There has been some pain in the right upper chest. Lately he has had a dry cough, especially upon arising in the morning. There has been some, though slight, loss in weight.

Examination showed a rather pale individual, in no apparent distress. There was fulness of the right upper thorax, restriction in respiratory movements over the same region, dulness on percussion down to the fifth rib anteriorly and to the scapular space posteriorly. Over the dull area, the breath sounds were diminished. There was evident ptosis of the right upper eyelid, slight contraction of the pupil as compared with the left, but no evident enophthalmos. Both radial pulses were present and of equal

volume. The right arm was slightly larger than the left, showing a difference of 4 cm. in circumference. There was cutaneous hyperæsthesia over the arm, but no other sensory changes. Muscular power good. The supra-clavicular veins on the right were somewhat prominent. The examination otherwise was essentially negative. X-ray of the chest showed a large circumscribed tumor of the right apical region.

Operative therapy was advised but refused. The patient was given a series of deep X-ray treatments with definite diminution in the size of the tumor, and increase in weight and a decrease in pain. This improvement, however, was only temporary. Six months later he was readmitted with his symptoms more pronounced than on the previous admission, with an increase in the size of the tumor and with paralysis of the diaphragm.

Operation was performed March 27, 1926. An incision was made anteriorly over the third rib, from the middle of the sternum to the axilla. The pectoralis major was split and about 6 inches of the third rib resected. The posterior periosteum of this rib was incised and the pleural cavity opened. The apex of the lung was attached to the lower pole of the tumor, but could be separated from it. It became apparent that the tumor could not be removed through the opening so the costal cartilages of the second and fourth ribs were divided transversely, close to the sternum, a procedure which, with a strong rib spreader, allowed an adequate exposure. Closer examination of the tumor showed it to be covered by the partial pleura, which was intimately connected with the capsule of the tumor. The tumor was satisfactorily surrounded to a small area, where it was densely and intimately fused with the subclavian vessels. Here, in attempting to separate the mass from the vessels, the capsule of the tumor was ruptured. From this point on, an intra-capsular removal seemed the only possible procedure. The tumor was completely removed except for a narrow strip of capsule attached to the subclavian vessels. There was surprisingly little bleeding during the procedure. The wound was closed without drainage. The diagnosis of the tumor was myxo-sarcoma.

Post-operative convalescence was satisfactory for a time. An effusion subsequently developed, which was tapped several times. Finally, a tube was inserted, after culture from the aspirated fluid showed staphylococcus. Five months after operation, an enlarged gland was found in the right axilla, which was taken to be a metastasis. X-ray of the chest showed a recurrence of the apical tumor. The patient from this time on, steadily went down hill and died within a year from operation. An autopsy was not obtained.

SUMMARY.—Of the 33 cases in the first and second series, two cases not tumors but an aneurism and a mediastinal abscess have been described because they illustrate the difficulties in diagnosis and were operated upon with the mistaken diagnosis of tumor. The 31 true tumors of the thorax included:

(1) Three sarcomas of the bony thorax (ribs).

(2) Ten tumors of the mediastinum including
  (a) Two congenital tumors, one teratoma; one calcified dermoid cyst.
  (b) Four benign tumors, one xanthoma; one chondro-myxoma; two undiagnosed.
  (c) Two malignant tumors, probably sarcomas or thymomas.
  (d) Two mediastinal Hodgkin's disease.

(3) Six tumors of the pleura including
  (a) Three diffuse endotheliomas of the pleura.
  (b) Three circumscribed endotheliomas of the pleura.

(4) Nine tumors of the lung including
  (a) Three primary carcinomas, one possibly an endothelioma.
  (b) Four primary sarcomas, one possibly an endothelioma.
  (c) Two metastatic sarcomas in which pulmonary symptoms were predominant.

(5) Two hour-glass tumors involving the thorax and spinal cord, one a neuro-fibroma, the other not verified.

(6) One apical chest tumor diagnosed as myxo-sarcoma.

Of the 31 cases, 15 were subjected to operation. In 14 of the remaining 16 tumors, the lesion was so advanced or of such a nature as to preclude operation; in two obviously benign lesions, the patients refused operation. In the 15 cases subjected to operation, the operation consisted of a radical removal of the tumor in nine, a partial removal or the drainage of infectious complications in five. There was one operative death occurring in the group subjected to radical operation. Of the cases subjected to radical operation, eight recovered, and of these, one (benign) is living ten years, one (benign) eight years, one (benign) six years, two (malignant) over two years, one (benign) less than one year. Two (malignant) died of recurrence within a year. Of the cases treated by partial removal, one lived over two years, the remainder died in about a year.

Of the 31 intra-thoracic tumors seen by me, only 11, or 35 per cent., were possibly operable. The mortality in those subjected to radical operation was 10 per cent. and the results not too pessimistic. Our experience warrants the assumption that with earlier diagnosis and earlier operative treatment, the surgery of intra-thoracic tumors may be greatly improved.

THE THORACO-PERITONEAL OPERATION FOR HERNIA OF THE DIAPHRAGM*

By Philemon E. Truesdale, M.D.
of Fall River, Mass.

The surgical mortality in dealing with diaphragmatic hernia varies from 5 per cent. to over 50 per cent., depending upon the physical state of the hernia revealed at the time of operation. When the stomach alone is involved it may become incarcerated, but not strangulated. Therefore, operation in this class carries a small risk. On the contrary, when the operation is undertaken for acute intestinal obstruction the mortality rate reaches the peak, unless a surgeon is called upon to deal with the situation early and finds conditions favorable. It is higher than the mortality for acute intestinal obstruction in general, because the operation for hernia of the diaphragm is not complete unless the aperture is closed. In accomplishing this the extra time and technical difficulties to be surmounted present a real hazard in the picture.

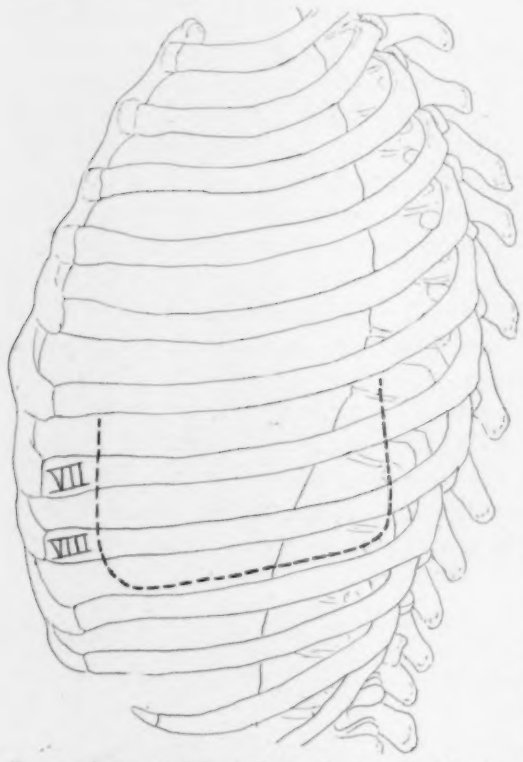

Fig. 1.—Interrupted line indicates the line of incision, including all layers of the thoracic wall.

To eliminate the danger of a major operative procedure and thus reduce the mortality from 50 per cent. to 5 per cent. is something to be desired. It can be done by a two-stage operation. First, an appendicostomy or cæcostomy to relieve the obstruction, and secondly, the operation for repair at a time of election. Here the application of the principle of the two-stage operation has special significance, since according to C. H. Mayo's observation the colon was found above the diaphragm in 12 cases out of 22. Hedblom's analysis of 343 cases also revealed the important fact that in more than 50 per cent. of these cases the colon was involved in the hernia.

Although the stomach and small intestines may pass through the opening in the diaphragm with the transverse colon, when constriction occurs the

* Read before the American Surgical Association, May 12, 1927.

seat of obstruction almost invariably is in the transverse colon. This liability no doubt is due to the inspissation and accretion of the contents of this segment of the intestine.

The preliminary operation of appendicostomy or cæcostomy promptly relieves the obstruction. If it so happens that the diagnosis of diaphragmatic hernia has been established, this minor operation eliminates the necessity of laparotomy and allows adequate time to prepare the patient for the major operation of repair. In addition, it provides a safety valve in case of recurrence or during convalescence when pressure against the reconstructed diaphragm from distended gut below can be reduced to a minimum. The use of the stomach tube before and after operation is also of great value, especially in those cases which involve the stomach alone.

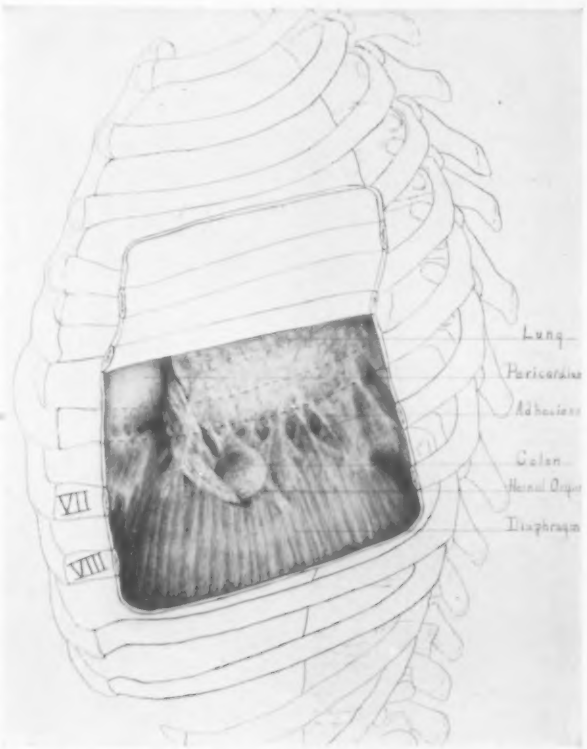

FIG. 2.—With the flap turned upward on its base, a large window is provided for dealing with the structures which come plainly into view.

An interesting case with obstruction was reported by Frank S. Mathews in 1920 (*Trans. Amer. Surg. Assn.*, vol. xxxviii, p. 614), another by John H. Jopson, (*Trans. Amer. Surg. Assn.*, vol. xxxviii, p. 625). In this case acute intestinal obstruction recurred twenty-four hours after the colon had been reduced by the peritoneal route. Jopson discovered the hernia in the diaphragm by an abdominal approach. He found it necessary, however, to supplement the abdominal incision by a thoracotomy in order to reduce the bowel, and sutured the diaphragm from above. A case described by Bevan (*Trans. Amer. Surg. Assn.*, vol. xxxviii, p. 623) involving the transverse colon was readily reduced and the aperture closed without difficulty. His patient died soon after operation from acute obstruction, which persisted on account of a circular carcinoma of the splenic flexure found at autopsy. Under circumstances of this sort a preliminary cæcostomy would relieve acute obstruction and permit opportunity for the röntgenologist to discover the neoplasm at the splenic flexure.

It is probable that, in more than 90 per cent. of the cases of dia-

phragmatic hernia which come to operation, all the entanglements above and below the diaphragm can be negotiated safely by either one of two approaches, the peritoneal or the thoracic. After a careful consideration of all the evidence in his case it is customary for the surgeon to adopt a plan of procedure which appears to be the most rational for him to undertake. Occasionally, on account of the difficulties encountered, it has been found necessary to abandon the chosen method and later operate again by another approach. Frank (ANNALS OF SURGERY, March, 1920,) found it necessary to abandon the attempt by laparotomy and at a second operation successfully closed the aperture in the diaphragm through an opening in the chest wall.

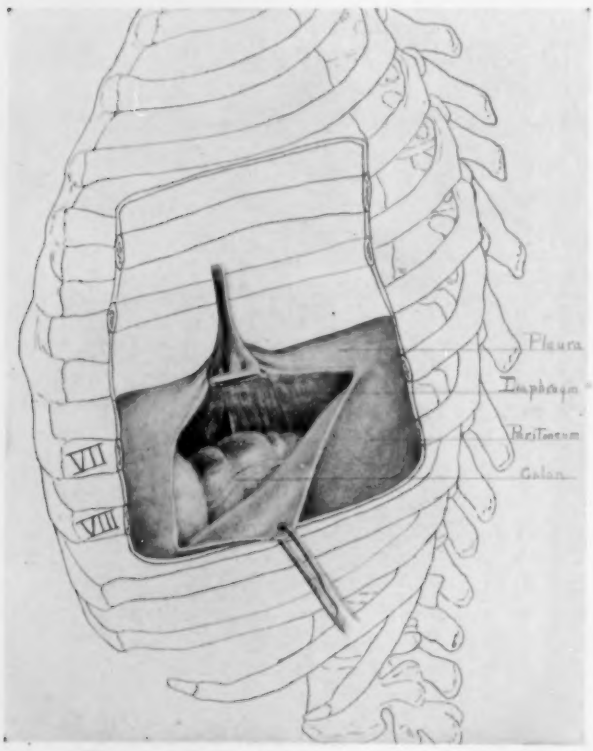

FIG. 3.—The right angle incision opens the serous cavities below the diaphragm as well as above it.

Another case of unusual interest was reported by Harvey B. Stone. The patient was operated upon for acute intestinal obstruction by Dr. Charles H. Watt who reduced the herniated colon without subsequently closing the opening in the diaphragm. Later examination revealed the presence of the colon in the left thoracic cage. Doctor Stone operated upon this patient through a high rectus incision, but found reduction of the incarcerated colon impossible. He then performed thoracotomy, exposing the upper surface of the diaphragm, after which he incised the constricted ring, bimanually reduced the herniated bowel and successfully closed the opening in the diaphragm. This operation he has described as the "Abdominothoracic Approach" (ANNALS OF SURGERY, July, 1923, p. 32).

Several other surgeons, including Greig, Granger, Mawson Ray, Weat and Dujarier have reported cases in which it was found impossible to close the opening in the diaphragm completely by the peritoneal approach. Fewer failures in completing the operation have been reported by those who selected the thoracic approach.

Among the French surgeons who invariably employed the transthoracic

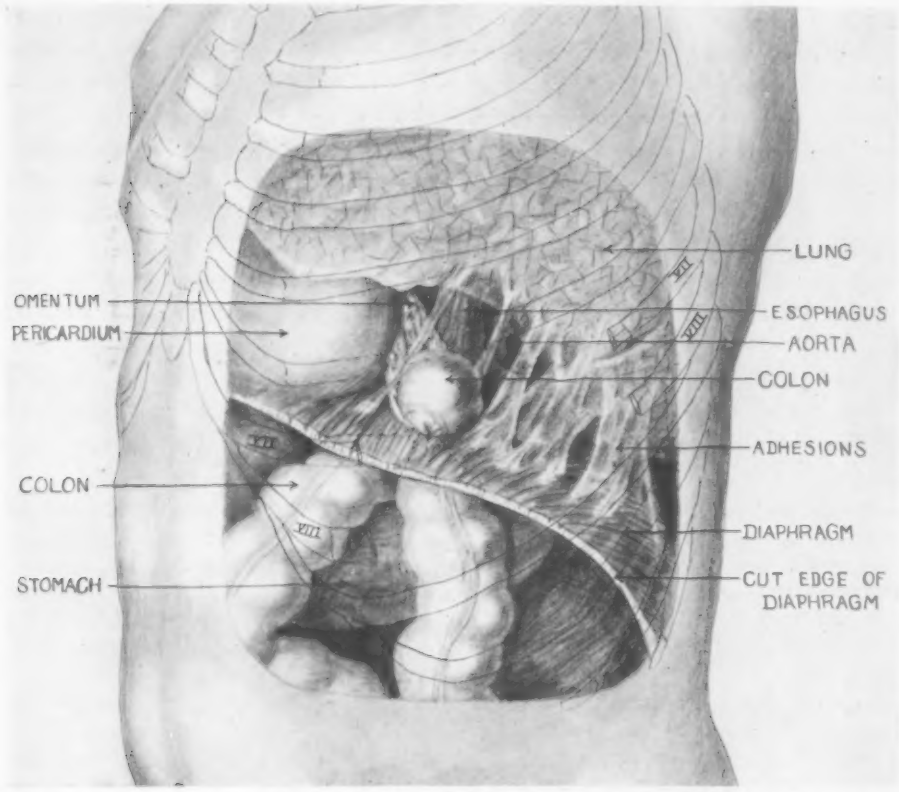

FIG. 4.—The section through the diaphragm portrays the conspicuous rôle of the transverse colon and omentum in the case reported above.

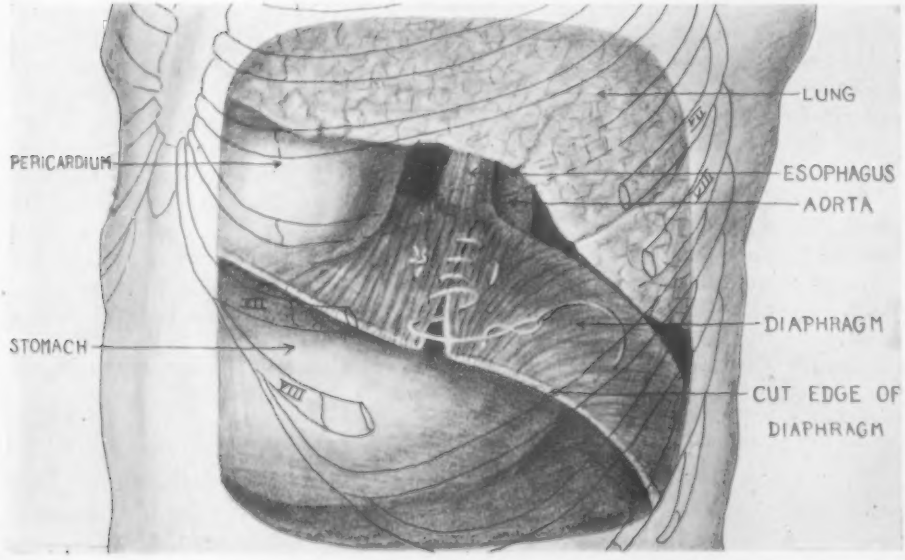

FIG. 5.—Aperture repaired by a running suture of chromic catgut, reinforced by mattress sutures of the same material.

approach Bedard and Auvray were the first to combine the opening of the pleural cavity and the peritoneal cavity by means of one incision. Bedard used the right-angle incision giving entrance to both thorax and abdomen. His case was one of strangulated hernia and came to autopsy. Auvray (*Bull. de la Soc. Chir.*, 1919, p. 698) was the first to employ the thoraco-peritoneal incision successfully. By means of a thoracic approach alone he was unable to free adhesions by the use of the bistoury, so he used a right-angle incision 41 cm. long, resecting the ninth rib and extending downward nearly to the umbilicus. On the twelfth day he was obliged to open the pleural cavity to evacuate sero-sanguinous fluid. I have not found this exact method of approach described elsewhere in the literature on surgery of the diaphragm.

The following case presents the combined problems of this singular anomaly in the form of a congenital hernia of the diaphragm with extensive adhesions above and below the aperture.

The patient was a girl aged six years, who was admitted to the Brockton Hospital in March, 1925 for acute intestinal obstruction. She was operated upon by Dr. Samuel Goddard. A diaphragmatic hernia was found and reduced, but owing to the inaccessibility of the opening in the diaphragm, no attempt at closure was made. After remaining well for nearly a year, in February, 1926, she awoke at night with severe abdominal pain and vomiting. She was readmitted and operated upon. Again the hernia was reduced, but an attempt to suture the opening in the diaphragm presented too many difficulties.

On March 14, she was admitted to our hospital. Röntgen-ray examination revealed a loop of the transverse colon above the diaphragm and located near the œsophagus. A preliminary appendicostomy was done on March 20th. On April 2 an attempt was made to close the opening in the diaphragm through an abdominal incision along the left costal margin. Although liberal in extent, this opening did not allow sufficient access to the hernia orifice to justify an attempt to deal with the incarcerated loop of colon which was found fixed at the point of constriction in the diaphragm. Since the hernia could not be reduced by traction of moderate force, the operation was abandoned. On April 26 a thoracic approach was made by means of a lapel incision over the sixth, seventh and eighth ribs. This flap of chest wall, including ribs, muscles and pleura was turned upward allowing an extensive exposure of the diaphragm. The mass representing the contents of the hernia included the colon and omentum. Difficulty was met in dealing with the adhesions at the ring, so the inner angle of the parietal incision was continued downward in a vertical direction opening the peritoneal cavity and exposing the under surface of the diaphragm. In order to expedite reduction of the colon and omentum, the diaphragm was split from the aperture toward the periphery. The adhesions thus were more readily released and the bowel and omentum replaced in the peritoneal cavity. The opening in the diaphragm was closed from the lowest point toward the periphery by running suture of chromic catgut reënforced by mattress sutures of the same material. The patient made an uneventful recovery. One year later she returned for closure of the appendicostomy. She had been well throughout this period since her operation.

TECHNIC OF THE THORACO-PERITONEAL OPERATION

The first steps of this operation should be conducted on the assumption that it will not be necessary to open the peritoneal cavity. In most cases a liberal exposure of the diaphragm through the chest wall will permit a complete reduction of the hernia and closure of the orifice without difficulty.

In any case it requires no more time to provide a large window in the thoracic wall. This is done by employing the lapel incision. Beginning at the lower edge of the sixth rib in the posterior axillary line, the skin is divided in a downward direction over the seventh and eighth ribs, where it makes a right angle turn and follows the eighth intercostal space in a forward direction until it reaches the cartilaginous portion where it turns upward, again crossing the seventh and eighth ribs, thus outlining a trap-door. The skin is not dissected off the parietal wall. Returning to the point of beginning the incision is carried through all layers of the chest wall including the pleura. The seventh and eighth ribs are severed in the path of the knife which follows the line of the original skin incision. The flap is thus completed and turned upward on its base. When it is deemed necessary to expose the underside of the diaphragm the vertical incision near the left border of the sternum is continued downward through the left rectus muscle for about six to eight centimetres. Incising the peritoneum, the diaphragm is then exposed above and below in such a manner as to permit the separation of all adhesions directly under the eye. The sac, if there is one, can be removed readily and its contents replaced below, thus permitting a speedy closure of the aperture. As in the case described above, it may be considered of advantage to split the diaphragm from its anterior edge down to the hernial orifice. This gives the appearance of a somewhat radical step, but it permits a better access to the ring and facilitates its closure, with a running suture of chromic catgut. This line is supported by mattress sutures of the same material. The peritoneal wall is then closed. The thoracic flap is then turned back in its place and closed tight with interrupted sutures of silkworm gut.

SUMMARY.—The two factors in dealing with diaphragmatic hernia which I wish to present in this paper are:

1. The two-stage operation in all cases involving the colon.
2. The thoraco-peritoneal operation as an added resource in time of need.

THE CHANGING STATUS OF ANÆSTHETICS*

By George P. Muller, M.D.
of Philadelphia, Pa.

No chapter in the history of Medicine is more fascinating than that relating to the development of anæsthesia. The literature now has assumed vast proportions and it is only possible to point out here and there certain events and names which have served as milestones in the path of progress. After the discovery of hydrogen, oxygen, nitrogen and nitrous oxide, whisperings were in the air, but nearly seventy-five years elapsed before Bigelow in 1846 made formal announcement of the discovery of ether as a surgical anæsthetic.

One year later Simpson's famous pamphlet on chloroform appeared and the claims for ether were challenged by the less irritating chloroform which maintained the advantage in England for many years and even in the United States was favored in the South and West until comparatively recently. In 1858, John Snow published the result of his work on animals showing the physiological effects of ether and chloroform, this being the earliest first-class piece of experimental work to be done but a good deal of the literature of the next decade was concerned with different types of inhalers and controversy as to whether anæsthetics had reduced or increased the mortality of surgical operations.

As early as 1800, Davy ventured the suggestion that nitrous oxide might be used during surgical operations, but the dentists, led by Colton, discovered its great value in 1863, and when in 1868, Andrews, of Chicago, suggested the admixture of oxygen to prevent asphyxiation, the medical profession was skeptical to the suggestion and nitrous oxide as a surgical anæsthetic lapsed.

In 1879, the first committee of the British Medical Association pointed out the danger of chloroform, and in 1881, Agnew considered ether as the anæsthetic of choice and believed that, generally, chloroform should be banished from surgical practice. He noted that nitrous oxide was quite unsuited to the purpose of general surgery. About the same time Gross stated a preference for ether on the ground of greater safety, but from the wording of his sentences one gathers the impression that chloroform was dear to his heart. He also believed that nitrous oxide could not be employed safely in protracted operations.

During the period from 1880 to 1900 the physiological aspects of ether and chloroform anæsthesia were studied but there was little progress. In 1897 the A.C.E. mixture began to have a vogue but in 1897, Horatio Wood wrote that the surgical profession had practically settled down to the employment of either ether or chloroform, and John Ashhurst (1897) taught that

* Read before the American Surgical Association, May 13, 1927.

ether was the anæsthetic of choice, nitrous oxide being seldom employed in general surgery except as a preliminary to the administration of ether. The ether-chloroform controversy was active, however, and in 1896 Caldwell (*Jour. A. M. A.*, 1896, vol. xxvii, p. 1289) sent a questionnaire to surgeons north of Baltimore and St. Louis. New York, Philadelphia and Boston used ether exclusively, Chicago was about equally divided, St. Louis was 75 per cent. for chloroform and further west chloroform was still more popular.

But as early as 1889, Gersuny reported eight major operations performed under nitrous oxide anæsthesia, Hewitt was giving gas, even for amputation, and by 1895 nitrous oxide induction preliminary to ether was being referred to in our literature. In 1898, Lilienthal (ANNALS OF SURGERY, 1898, vol. xxvii, p. 583) wrote an excellent paper on local and nitrous oxide narcosis and reported four major operations done under gas. He reported a number of operations with eucaine, an anæsthetic just discovered. In 1900, Goldman (*Jour. A. M. A.*, vol. xxxiv, p. 708), of New York City, wrote a rather advanced paper for the time on the use of nitrous oxide anæsthesia in prolonged surgical operations. He advised the nitrous-oxide-oxygen-ether sequence in abdominal operations, wrote of certain advantages of carbon dioxide rebreathing from a bug and of the admixture of oxygen with the gas. Parenthetically, it is interesting to recall that in 1894, W. J. Mayo reported that he had performed seven operations on the gall-bladder and biliary tract and Deaver and Murphy were starting the campaign against the appendix.

In 1901, Crile (*Southern Med. J.*, 1901, p. 20) began publishing the series of papers revolving about the use of nitrous oxide as an anæsthetic and stated that he had used it in 575 major operations. Apparently at first he did not combine it with oxygen but did use morphine-scopalamine as a preliminary. In the same year Bennett (*Ref. Handbook Med. Sc.*, 1901, vol. iii, p. 19) was uncertain as to the safety of nitrous oxide and oxygen for prolonged administration.

The extended use of nitrous oxide was somewhat delayed by the introduction of the so-called "open-drop" method of administering ether, first developed by Prince in 1893. This method was largely popularized by visitors returning from the Mayo Clinic where Alice Magaw gave preference to ether and wrote in 1906 that ether comprised 92 per cent. of the anæsthetics given during the year 1905. Prior to the open-drop method various inhalers and cones had succeeded the apparatus of Clover which had followed the flask of Morton, and it is interesting to recall that Clover made use of the modern principle of rebreathing, but the method was given up in the '90s because it was thought that the rebreathing of exhaled gases poisoned the patient.

If we turn back a few years we find the sources of a new method of anæsthesia and one destined to forge up to the front rank. In 1880, Von Anrep suggested the possibility of cocaine by injection as a surgical anæsthetic, but the idea was not followed up. In 1884, Koller demonstrated the anæsthetic properties of this drug on the eye and his paper attracted world-

wide attention. In the same year Halsted injected a solution of cocaine along the course of sensory nerves and operated for talipes by this method. In the following year Leonard Corning, of New York, injected cocaine on to the dural sheath of the cord, the forerunner of the modern sacral anæsthesia, but it was not until 1898 that Bier introduced the present method of injection into the sub-arachnoid space. In 1894, Schleich introduced the use of dilute solutions of cocaine and in 1897 eucaine was discovered, the first of a long line of similar local anæsthetics. Casey Wood brought Schleich's solution to the attention of American surgeons, and this marked a distinct advance because a long list of fatalities had been reported from the use of stronger solutions.

In 1900, Matas published his masterly paper on local and regional anæsthesia and called attention to the fact that Crile had amputated a leg in 1897 after injecting the sciatic and anterior crural nerves. Matas made the following remark: "With Lilienthal, I would say that we have accustomed ourselves to ether and chloroform to such an extent that only in very exceptional cases do we think of the possibility of doing serious surgical work without them. Yet there are many major operations which can be better and more safely done with the help of local anæsthetics, and it is merely the force of habit that keeps us in the old rut." Abroad, many operations were done under local anæsthesia and Kocher was routinely doing thyroidectomies by this method, but in this country except for minor procedures the method made slow progress, and even in 1914 Balfour stated that during 1913 they had performed *several* abdominal operations under novocaine alone.

In 1910 a great impetus was given to gas anæsthesia by the publication of Crile's anoci association technic and most of us who visited his clinic were deeply impressed by the smoothness of the anæsthesia.

About this time two events occurred in this country that had an important bearing on the anæsthesia question. In 1911, this association had a symposium on anæsthesia and Bevan, Gatch, Meltzer, Henderson and Crile read the papers. Among Bevan's conclusions he stated: That for routine work, open drop ether is the safest and most satisfactory anæsthetic, and in the usual run of good surgical risks it is the anæsthetic of choice in from 75 to 80 per cent. of the cases. Nitrous oxide should not be preferred to ether in the ordinary prolonged operation in patients who are good surgical risks. Local anæsthesia has a limited field of usefulness. Spinal anæsthesia has little or no place in surgery. The use of morphine and scopalamine before a general anæsthetic should be abandoned or limited to specially selected cases.

On the other hand, Crile gave us the official presentation of his principle of anoci association. He urged the use of morphine and scopalamine especially on the ground that it depressed the faculty of associated memory and thus abolished fear. He urged the use of nitrous oxide and oxygen as minimizing shock by limiting oxidation in the brain tissue.

Gatch revived the old principle of rebreathing as exemplified in the

Clover inhaler. The use of the closed inhaler permitted a certain amount of rebreathing, but when the open method came into use it was considered a great advance in that the patient could get rid of the CO_2 more easily. The physiologists, especially Henderson, then showed there were no organic poisons in the expired air and that CO_2 was not only harmless but useful. This led Gatch in 1910 to advocate the deliberate use of rebreathing as an aid to good anæsthesia, the gas machines were changed to fit the Gatch principle and at the same time McKesson introduced the principle of fractional rebreathing.

In 1907, the Anæsthesia Commission of the American Medical Association was formed and in the following year Mumford made the preliminary report. They believed that open-drop ether was the safest anæsthetic, and regarded the use of nitrous oxide with air throughout major operations as a novelty. Haggard reported that he had performed three major operations under nitrous oxide and Mitchell wrote an excellent report on the use of local anæsthesia stating that "except for strictly minor operations, the use of local anæsthesia in America is limited to a few clinics." This commission made its second report in 1912 and put the final quietus to any official claim for chloroform in this country, believing that in neither major nor minor surgery there was any justification for its use. Yandell Henderson was the chairman and his well-known views regarding acapnia led to the strong approval of the principle of re-breathing and the use of CO_2 mixed with the oxygen. To me, the most important point made by them was that ether anæsthesia should always be induced quickly and thereafter kept as nearly uniform as possible. In 1912, Gwathmey (*Jour. A. M. A.*, 1912, vol. lviii, p. 465) attacked the ether drop method, preferring the use of vapor. It is interesting to note that at this time he believed that "as a broad general proposition, and when properly administered, ether or chloroform anæsthesia is as safe and also as free from after-effects as is a nitrous oxide and oxygen anæsthesia." In 1914, he advocated a nitrous oxide-oxygen-ether sequence. But open drop ether was the method of choice in the clinics of Mayo, Bevan, Murphy and Deaver. At the Mayo Clinic, McGrath (*St. Paul Med. J.*, 1914, p.83) found that from 1900 to 1913, ether was used in 94 per cent. of the anæsthesias. After 1907 chloroform was only used once. Henderson (*St. Paul Med. J.*, 1914, p. 74) wrote that "to-day we are going through a curious phase in the use of anæsthetics, namely, a return to narcotics, inefficient nitrous oxide, and local anæsthesia, a combination which has the bad qualities of all three, and in which the local anæsthesia does most of the work." In 1910, Meltzer brought up the possibilities of endotracheal anæsthesia and the method was adapted to clinical use by Elsberg. I was among the guilty ones who devised an apparatus for this purpose and for several years was very partial to it for operations on the mouth and neck. Shipway in England still uses it and in 1921 reported an experience of 930 cases. But during the War Gwathmey and Bunnell showed that positive pressure could

be obtained with the gas mask and Graham's studies minimized the dangers of acute pneumothorax.

In 1915, Bevan again (*Jour. A. M. A.*, 1915, vol. lxv, p. 1418) concluded that "drop ether" should be considered as the standard general anæsthetic and that gas should be chosen in short anæsthesias in which unconsciousness is desired and especially when there is kidney insufficiency. He favored local anæsthesia with novocain but did not believe its range should be stretched too far. He rejected spinal, intravenous and intrarectal methods. He rejected both the theory and practice of anoci association. But in some clinics gas-oxygen was in high favor. For instance, in 1912, Prince (*Jour. A. M. A.*, 1912, vol. lviii, p. 1342), of Birmingham, Ala., reported that he had operated on 2000 patients under gas-oxygen alone during four years, most of them major surgical procedures. For various reasons nitrous oxide and oxygen continued to grow in favor and by 1918 was soundly established as a standard anæsthetic and in sharp conflict with ether for supremacy.

Since the introduction of the method by Bier in 1898 spinal anæsthesia has had a steady but slight vogue, although a few men, notably Babcock in this country, have made extensive use of it. The improved methods of inducing local anæsthesias have reduced its selection even in strangulated hernia and in prostatectomy.

In the 1911 discussion on anæsthesia before this association Nancrede made a plea for chloroform in war surgery and said it was absolutely foolish to talk about giving ether after a big battle because enough ether could not be carried. When the war came three years later ether was supplied after the second month and gas machines and the Shipway apparatus were freely used.

During the war nitrous oxide and oxygen received a great impetus as an anæsthetic for shocked patients and local anæsthesia was more freely used than ever, especially for abdominal and head injuries, Cushing showing that extensive operations on the cranial cavity could be done under local anæsthesia and the idea was carried over into civil surgery, Elsberg recently reporting that he did 63 per cent. of major craniotomies under local anæsthesia.

The use of local anæsthesia on the surface and the early infiltration methods were comparatively simple, but when its use was extended to the abdomen and chest the problem became complicated and led to a minute study of the anatomical pathways and the sensory nerve apparatus. When it was found that the sympathetic alone carries sensory impulses from the abdominal organs, the problem resolved itself into an attempt to block the sympathetic ganglia. In 1913, Kappis injected the splanchnic nerves as they enter the semilunar ganglia and his results aroused the efforts of others, notably Braun and Wendling. In this country Labat called attention to splanchnic anæsthesia about five years ago. He believes that it has a very great field, without contra-indications. Blake (*J. A. M. A.*, 1924, vol. lxxxiii, p. 427), on the other hand, objects to the Kappis technic as being unreliable and dan-

gerous. Farr (*J. A. M. A.*, 1924, vol. lxxxiii, p. 429), as well as Blake, prefers an anterior sympathetic anæsthesia. In several papers published very recently by Lundy (*Surg. Clin. N. Amer.*, 1925, vol. v, p. 887; *Ibid.*, 1926, vol. vi, p. 1385; *Minn. Med.*, 1926, vol. ix, p. 399) from the Mayo Clinic it was shown that splanchnic anæsthesia was satisfactory in about 55 per cent. of the cases. He believes that its use is justified in certain well-selected cases, or when general anæsthesia is almost entirely contra-indicated. I note from his 1926 paper that apparently the method is less popular than it was earlier and he is "convinced that balanced anæsthesia is a more uniformly satisfactory anæsthesia than that provided by posterior splanchnic block." My own experience is limited to twelve cases. We are fearful of the great drop in blood-pressure which almost invariably occurs.

In 1917, Cotton introduced the ether known as Cotton Process ether. Standard ethers contained about 1 per cent. of ethylene, but this ether contained 2 per cent. and its virtues were supposed to be due to the action of this gas as a synergist. It is interesting that Lumbard in 1920 (*Am. J. Surg. Anæsthes. Supp.*, 1920, vol. xxxiv, p. 117) queried the possibilities of the ethylene as an anæsthetic but dismissed it as being an inert gas similar to nitrogen. Brown (*Canad. Med. Assoc. J.*, 1923, vol. xiii, p. 210) and simultaneously Luckhart and Carter (*Jour. A. M. A.*, 1923, vol. lxxx, p. 765) experimented with this gas in 1923 and the publication of their reports has led to a wave of enthusiasm over its merits. Abroad, acetylene has had a vogue. Ethylene has been used in my clinic since July, 1925, and we have observed all of the advantages claimed for it by Dean Lewis and others. The most serious objection to its use is the possibility of an explosion, but this can be minimized by certain precautions. Following a preliminary report in 1926, Sherman (*Jour. A. M. A.*, 1927, vol. lxxxviii, p. 1228) recently has reported in full his investigation of contamination of ethylene by carbon monoxide and believes it may constitute a real hazard. After the appearance of his paper last June, Dr. Selling Brill of our clinic examined seventeen of the tanks used and failed to find any evidence of carbon monoxide.

My own experience with anæsthesia began in 1904 when I first began to operate and at first practically all operations were done under straight ether by the open drop method. In 1905 we began the induction with nitrous oxide in the University Hospital, but for many years nitrous oxide-oxygen was only used alone for minor operations. About 1915, I began occasionally to use gas for major surgery and a year later was able to carry a subtotal gastrectomy through by this method with the addition of a very slight amount of ether. The table on page 250 shows the later progress of the clinic, the figures being given in percentages as the operations of the first year numbered 844 and during the fourth year 1132.

During 1926, in nearly all abdominal operations in which gas (nitrous oxide or ethylene) was used there was a reinforcement with local novocaine for the abdominal wall. Local infiltration anæsthesia is used alone for many cases of chronic appendicitis and hernia, for gastrostomies, enterostomies,

and colostomies, etc. It is usually used for acute empyema and for limited thoracoplasty. Simple cholecystostomy is sometimes done under local.

Gas anæsthesia, and almost always ethylene now, is the next anæsthetic of choice in my clinic. We never hesitate to add a little ether at times to

Table, in Percentages

	Sept. 1922–23	Sept. 1925–26.
Local, novocaine	10	22
Straight ether	43	11
Nitrous oxide—o	25	33
Ethylene	0	15
"Gas" ether	17	14
Miscellaneous	5	5

secure relaxation but try to avoid it in the presence of shock, acute toxæmia, diabetes, jaundice, exophthalmic goitre, and deficient kidney function.

Straight ether is used in small children, in operations about the face, and when relaxation is impossible from the other gases.

Special methods such as para-vertebral injections for thoracoplasty, splanchnic anæsthesia, sacral anæsthesia, and spinal anæsthesia, are only occasionally made use of.

Personally, I prefer inhalation anæsthesia and the nitrous oxide-ethylene-ether-local sequence is the choice, cutting out the ether whenever possible. All patients received morphine and atropine one-half hour before operation, unless contra-indicated. I have always been a firm adherent of the principle of Crile that the abolishing of the brain impressions during operation is a good thing for the patient. However, I find that I must use local anæsthesia more frequently than I like because of the wish of the patient and the preference of the medical advisers. Each year we have an increasing percentage of patients who refuse ether and together with the greater all-round safety of nitrous oxide and ethylene this will lead in time, I believe, to the relegation of ether as a straight anæsthetic to the obscurity which now envelops chloroform.

No mention has been made of the physiologic or pharmacologic aspects of anæsthetics in this rapid and cursory review. Steadily through the years innumerable observations have been made through experiment and such have had a pronounced influence on the practice in the larger clinics which has then radiated to general surgical practice. No mention has been made of endotracheal or rectal anæsthesias because after all they are only methods for inducing ether anæsthesia.

In conclusion, I believe that to-day, local anæsthesia and gas anæsthesia (nitrous oxide and ethylene) each with its own indications, are the anæsthetics of choice and that straight ether has only a limited field which will get less as time goes on.

THE PRESENT STATUS OF ANOCIATION*

A CRITICAL REVIEW

By George W. Crile, M.D.

of Cleveland, Ohio

It is approximately seventeen years since the combination of anæsthetics and the development of the special operative management, which together we term "anociation," was first proposed, on the basis of the findings in researches as to the cause of surgical shock, which had at that time already been in progress for approximately fifteen years. During these seventeen years the researches have continued and operative methods and operative management have been modified, but the fundamental principle upon which the original conception was based has remained unchanged. We still believe that the minimizing of post-operative morbidity and the reduction of operative mortality demand the protection of the patient as a whole from the deleterious psychic, as well as traumatic effects of the operation. We still believe that each case must be strictly individualized and that no one can say in advance that this or that combination of methods will be applicable to every case.

In our original conception, we centred our attention on the brain and central nervous system as the parts of the organism which primarily required protection if the energy of the body was to be conserved. With the central nervous system we have now linked the liver in an indissoluble union of activity and of function and our efforts are directed to conservation of the liver as well as of the central nervous system in the management of our patients.

Seventeen years ago we believed that in nitrous oxid oxygen we had the inhalation anæsthetic, the use of which combined with local anæsthesia, provided the utmost protection to the cells of the central nervous system, as contrasted with the deleterious effects of the lipoid solvent anæsthetics. We still believe in nitrous oxid oxygen as the inhalation anæsthetic of choice; but we now rarely induce more than the stage of analgesia. Paradoxical as it may seem, the more serious the risk the less the amount of inhalation anæsthetic that is administered.

In the early days of the application of the principle of anociation we laid stress upon the importance of transporting timorous patients—in particular patients with hyperthyroidism, to the operating room under narcosis with morphin and scopolamin. A little later, still further to minimize the psychic effect of the journey from the patient's room to the operating room, the patient was anæsthetized in his room and conveyed under anæsthesia to the operating room. To-day we bring the operating room to the patient,

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that is, the operation is performed in the patient's room without moving the patient from his own bed.

We formerly advocated the use of hot packs and the introduction of hot water to the abdominal cavity upon the completion of an abdominal operation in order that an optimum temperature might be conserved. We now more efficiently and adequately provide such an optimum temperature—of the liver in particular—by the application of diathermy before, during, and after the operation. In cases in which the abdominal viscera must be widely exposed, this measure of itself alone has doubtless saved lives and markedly diminished post-operative morbidity.

Before the war, and especially after we had observed in France the beneficial effects upon wounded soldiers of exposure to sun and electric light, we advocated the light treatment in certain cases. We have extended this principle by utilizing the energy of the sun as reproduced by the quartz lamp and apply this therapeutic measure in certain cases. This is of particular value in cases of patients exhausted by wasting disease and in the preparation and post-operative care of aged patients in whom, by diathermy and the use of the quartz lamp, the danger of post-operative pneumonia is minimized.

We have secured increasing evidence during these years that the circulation of energy is like the circulation of blood, and that therefore the organ or organs which govern the circulation of energy should be protected and stimulated just as the organ which governs the circulation of blood—the heart—is protected and stimulated by digitalization. We have therefore made it our prime aim to assure the circulation of energy by protecting and promoting the activity of the two dominant organs, the brain and the liver.

We have had impressed upon us increasingly during these years the importance of meeting the emergency *in advance*, that is, we have learned to apply the principle of prophylaxis to surgical practice. To this end protective measures are applied in advance of the possible emergencies during the pre-operative period—the heart, kidneys, and the general morale of the patient being brought to the highest possible degree of efficiency before the operation is performed. In no case do we wait until a vital emergency has developed, provided the emergency is one which we know by experience or by analogy may develop in any group of cases. We still place our principal reliance upon maintaining the internal respiration of the cells by assuring an abundance of their fundamental requirements, namely, water and oxygen. The supply of the former is assured by urging water through every route, in particular by its administration by hypodermoclysis—the quickest route whereby it may reach the cells; the supply of the second is assured by securing an optimum circulation of the oxygen-carrier—blood, by the transfusion of blood and by strengthening and protecting the myocardium by digitalis. An optimum supply of water, an optimum supply of oxygen, an optimum temperature, and optimum rest of the organism as a whole and in particular

of the brain and the liver, are still our principal conservative and restorative agents.

It may be well to review briefly in a little more detail the methods which are employed in those conditions which are generally conceded to be "bad risks"—acute hyperthyroidism, ulcer or carcinoma of the stomach, diseases of the gall-bladder, especially those associated with jaundice, peritonitis, carcinoma of the colon and rectum, diabetic gangrene. Whichever of these conditions may be present in the individual case, the following fundamental measures are employed: Two thousand c.c. of normal saline solution is given by hypodermoclysis—1/32 per cent. of novocain being added to this solution in accordance with Bartlett's method, to minimize discomfort. This is given once or twice a day together with 1/6 of a grain of morphin. To strengthen the myocardium, from four to six doses of digitalis—2 c.c. each—are given every four hours, these being followed by 20 minims twice a day. If anæmia or cachexia is present a transfusion of about 500 c.c. of blood is given and repeated if necessary. In every case the patient's blood is grouped upon his admission to the hospital in order that a donor may be at hand when needed. This is done in every case, whether or not the patient is classed as a bad risk, in order that there may be no delay should an entirely unexpected emergency arise.

If the heart is implicated to the extent that œdema or anasarca is present, especially in cases of hyperthyroidism, ammonium chlorid, 15 gr. four times a day for two days, is given followed by novasurol given intravenously in doses of from ½ to 1 c.c. every three or four days. This last measure has proved of such value that in many cases of hyperthyroidism, in which upon the admission to the hospital an operation seemed to be entirely contraindicated because of the condition of the heart, the ligation can now be eliminated and a partial resection can be made the primary operation. This result, however, is due in part, possibly primarily, to the use of Lugol's solution which is given in doses of 15 minims, three times a day, the operation being performed when the maximum effect of the Lugol's solution is reached, which is usually in about ten days.

In every case, whether it be an operation on the thyroid gland or within the abdomen, the operation is arrested at any moment at which the condition of the patient may indicate that further procedures can be but poorly borne. It is far better to arrest the operation and delay its completion until physiological balance is established than to push the organism so far that recovery will be delayed, even if life itself is not lost. In general, even if no preliminary ligation is performed, the lobectomies are separated by periods of twenty-four hours, the wound being packed open with gauze impregnated with a 1 to 5220 solution of flavine. By this means the surgeon begins his work on the following day exactly where it was discontinued the day before. Rest is assured during both the pre-operative and the post-operative periods by the administration of from ½ to 3 gr. of luminal, which is given in

preference to other narcotics or hypnotics, although morphin is used as indicated excepting in any case in which jaundice is present.

In cases of carcinoma of the stomach a resection with a wide excision of the growth is indicated. Here, as in operations upon the thyroid gland in cases of acute hyperthyroidism, a divided operation suffices to carry through many patients in whom the prognosis appears to be hopeless.

In cases of gall-bladder disease special precautions are taken to protect the liver against damage by the operation or by exposure. The fact that the liver cells have already been damaged, particularly in cases in which jaundice is present, is always borne in mind. The prevention of hemorrhage and the establishment of adequate drainage are the prime requisites in the protection of the liver. After operations upon the gall-bladder, drainage is established through the most dependent area, *i.e.*, through Morrison's pouch, the patient being kept in Fowler's position. In cases of peritonitis we still utilize the old Alonzo Clark method by administering morphin in sufficient amount to keep the respiratory rate at from 16 to 18 per minute. Dependent drainage is established and the patient is kept in Fowler's position. Here also the operation is interrupted if the condition of the patient demands it, no attempt being made to remove the source of infection, whether it be the appendix or some other focus, until the optimum moment for the operation has been reached. In cases of carcinoma of the large intestine or colon, obstruction is first relieved by means of a colostomy and again the major operation is postponed until physiological balance has been established.

In cases of patients with diabetes we are now able to apply the natural remedy, insulin, and by its aid to carry through operative procedures which formerly would have been contraindicated. This applies not only to cases of diabetic gangrene, but to any other operation which may be indicated as necessary in a diabetic patient. These patients are placed under the immediate care of Dr. Henry John, the head of our Diabetic Department, who indicates when an operation is compatible with the diabetic condition. Since the advent of insulin no deaths which could be attributed to diabetes have followed operation.

To reiterate briefly: Hypodermoclysis, an adequate supply of oxygen secured by digitalization of the heart and by the transfusion of blood; an optimum temperature secured by means of diathermy; additional energy induced by the quartz lamp; minimum trauma; divided operation; general anæsthesia carried only to the stage of analgesia, with prime reliance upon regional anæsthesia; feather-edge bloodless dissection; dependent drainage; the application of all known methods for promoting the optimum function of the heart and kidneys, environmental control; adequate sleep and rest—all these together constitute the armamentarium which we have designated by the term "anociation".

ETHYLENE AS AN ANÆSTHETIC FOR GENERAL SURGERY*

By Hugh Cabot, M.D.

and

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We have been using ethylene extensively as a general anæsthetic for a period of about three and a half years and during this period have employed it in 11,607 cases. This appears to be a number sufficient to warrant an attempt to draw approximate conclusions in regard to its value. As a candidate for acceptance in this field, it must be compared with ether and chloroform, on the one hand, and nitrous oxide and oxygen on the other. It is not, we think, necessary to discuss its relation to local, regional, spinal or sacral anæsthesia since the indications for these methods must stand upon different bases. During this period all of the patients have been anæsthetized by trained women anæsthetists under the supervision of our Chief Anæsthetist, Miss Laura M. Davis. This is the same group which has been administering anæsthetics for us over a considerable period and it therefore makes comparison with other anæsthetics satisfactory. Our usual custom is to give morphine from a sixth to a quarter of a grain and atropin one hundred fiftieth from fifteen minutes to half an hour before operation. In the number of cases above referred to ether has been sometimes used mixed with ethylene and in a relatively small proportion, has been the chief anæsthetic. In about 70 per cent. of these cases, ethylene alone was used. In about 27 per cent., ether vapor was given with ethylene, and in about 3 per cent. ethylene was used only for induction and the balance of the operation was done under ether administered by the drop method. These proportions seem to agree fairly accurately with those reported by other observers of considerable experience.

Induction.—The stage of induction is rapid, practically the same as that with nitrous oxide but in contradistinction to the latter, the color remains good throughout. We have noted no greater tendency to initial nausea.

Apparent Effect on the Patient.—Throughout the operation the appearance of the patient has been good. There is a striking absence of the occasional cyanosis relatively often seen with nitrous oxide and oxygen, this being due to the fact that larger amounts of oxygen can be given and yet obtain full anæsthesia. It should be noted in this connection that the danger associated with the administration of nitrous oxide appears to exist only during the presence of cyanosis and it has been generally believed that if cyanosis could have been entirely eliminated in the administration of the latter gas its

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undoubted danger would have been greatly diminished. It, therefore, appears that the elimination of cyanosis under the use of ethylene contributes considerably to the probability of its proving to be a safe anæsthetic. The absence of sweating has been notable particularly as compared with ether and to a somewhat lesser extent with nitrous oxide. Anæsthetic recovery is prompt, practically the same as that with nitrous oxide. To some extent this prompt recovery from anæsthesia induced by gas is not altogether desirable since it has the effect of subjecting the patient to the full effect of the pain consequent upon the surgical trauma which was considerably mitigated by the slow recovery from anæsthesia with ether or chloroform. Where gaseous anæsthetics are used we have found it necessary to administer morphia more promptly after operation and in a somewhat larger per cent. of cases.

Nausea and Vomiting.—The incidence of nausea and vomiting has been substantially like that of our previous experience with nitrous oxide. It may occur during the stage of induction, may occur during anæsthesia if it become unduly light, and is common during the brief period of anæsthetic recovery. The prolonged nausea and vomiting relatively common after the administration of ether or chloroform is importantly less with ethylene. The proportion of cases in which nausea and vomiting persisted for hours and occasionally for days is small and we have been unable to separate it from the same symptoms related primarily to the operation and not particularly to the anæsthesia. We have not thought that ethylene had any advantage in this particular over nitrous oxide, but are quite clear that it has a very distinct advantage over ether or chloroform.

Muscular Relaxation.—One of the important purposes of anæsthesia is to give muscular relaxation and the extent to which this is achieved by any general anæsthetic is of some importance. The most complete relaxation is probably obtained by chloroform but entirely satisfactory results are obtained with ether. In our experience it was never possible to get the highest degrees of relaxation particularly in abdominal operations under the use of nitrous oxide and oxygen. Our experience with ethylene has been that it occupies a position somewhere nearly half-way between ether and nitrous oxide in this regard. There have been a considerable group of patients chiefly with operations in the upper abdomen, often upon the stomach or gall-bladder, in which the requisite degree of relaxation could not be obtained with ethylene or even with reasonable admixture of ether vapor. It is chiefly this group that makes up the three per cent. of cases in which ether was administered practically exclusively. Muscular relaxation is relatively more important in abdominal surgery and our experience with surgery other than that of the abdomen has been that ethylene was wholly satisfactory from the point of view of relaxation. In strong muscular individuals, and particularly when dealing with lesions deeply placed in the upper quadrant of the abdomen, ethylene has not in our hands been a wholly satisfactory anæsthetic and we do not expect to employ it in these cases as a routine method.

The Effect on Blood-pressure.—One of the questions properly asked of

a candidate for credit among anæsthetics is the effect upon blood-pressure. A study of a moderate number of our cases appears to show that there is very commonly an initial rise of blood-pressure amounting on the average to about 17 per cent. In our observations the extremes varied from 0 to 55 per cent., the latter figure being rarely reached. This rise occurs promptly and falls off rapidly during the subsequent half hour, returning to normal at about that time. It has appeared to us that there was somewhat more bleeding during the early stages of the operation than occurred with ether, though not importantly different from that seen with nitrous oxide. It is not impossible that this observation is related to the initial rise in blood-pressure and may constitute a relative contra-indication in certain groups of cases. For instance, a dry field is of enormous importance in brain surgery and in this field we have entirely abandoned the use of ethylene and in fact, rarely use any general anæsthetic. Most of these cases have, during the above period, been carried on under local anæsthesia, and where a general anæsthetic has been employed, ether has been selected.

This apparent effect upon blood-pressure has some bearing upon the value of this anæsthetic in the presence of shock. It was, we think, satisfactorily shown some years ago, though confirmed by the experience during the war, that nitrous oxide and oxygen was altogether superior to ether or chloroform as an anæsthetic under these conditions. This was partly due to their effect upon blood-pressure and also to their effect upon the alkali reserve. In our experience, ethylene has been quite the equal of nitrous oxide for patients in shock and we think, therefore, that it may be accepted as preferable to ether or chloroform under these conditions.

Effect on Kidney Function.—There has been relatively little study of the effect of general anæsthetics upon kidney function. In 1915, one of us (H. C.), in conjunction with Richard Miller, made a fairly careful study of the effect of ether upon kidney function as tested with phthalein. My junior colleague, C. E. McDermid, has carried out a similar study for ethylene based upon examination of one hundred eighty-four cases. (See McDermid's "A Comparative Study of the Effect of Ethylene and Ether Anæsthesia upon Kidney Function as Shown by the Phenolsulphonephthalein Test"—unpublished communication). Without going too much into the details of this study his results appear to show that ethylene has less effect in diminishing kidney function than ether. Thus in 335 cases of operations of more than thirty minutes' duration, Miller found an average diminution of output of 19 per cent. while McDermid, in 106 cases, found an average diminution of 14 per cent. In operations lasting from one to two hours Miller found an average diminution in 95 cases in which ether was administered, of 23 per cent. while McDermid, in 61 cases of ethylene anæsthesia, found a diminution of 14 per cent. It is, we think, safe to conclude that ethylene has a less deleterious effect upon kidney function than ether. We are by no means clear that the relatively slight diminutions observed by McDermid can be credited to the anæsthetic at all and incline to the view that quite similar

results would be obtained in a study of patients in whom the same operations were carried out under regional or local anæsthesia. In other words, we suspect that it is the operation rather than the anæsthesia which is accountable for the changes.

Pulmonary Complications.—One of the most valid charges against ether has been its liability to cause irritation of the respiratory tract, occasionally leading to grave post-operative complications and also to light up latent tuberculous lesions which were satisfactorily quiescent. In this regard it has been quite certain that nitrous oxide was altogether superior to ether and if the claim of ethylene to displace nitrous oxide is to be substantiated, it must show an equally satisfactory result. Our experience in the considerable group of cases has been that ethylene is quite as satisfactory as nitrous oxide in this particular. We have no record of any case of post-operative pneumonia where ethylene alone was employed. In about 4 per cent. of the cases in which ether was used with ethylene, various degrees of bronchial irritation and bronchitis have occurred. There have been three cases of frank post-operative pneumonia also in this group. These figures are based upon the assumption that respiratory complications consequent upon the anæsthetic will show evidence of their presence within five days.

Danger of Ignition or Explosion.—The most serious question which confronts those who would use ethylene as a general anæsthetic is in regard to its inflammability or explosibility. This question has been much discussed and we have little to add except a statement of our own experience. We can contribute nothing to the facts already presented in regard to the dangers of explosion since no case has occurred in the above-mentioned group. During the same period there has been one explosion of an anæsthetic apparatus not in use but in this case the exploding mixture was ether. We think there can be no discussion in regard to the absolute necessity of avoiding naked flames or sparks in or near the operating room. This prohibition, we think, is absolute, and if gas flames, electric sparks or cigarette smoking members of the staff cannot be excluded, the use of this anæsthetic is contra-indicated. This property also vetoes its use where the cautery, the endotherm or any form of electrical current involving a spark is to be used. It seems quite certain that ethylene is not explosive in the mixtures used for anæsthesia. It is the lean mixtures below those satisfactory for anæsthesia that are explosive. There has been much discussion of the importance of static sparks in the causation of accidents. In regard to this we can only say that we have not found it necessary to use any of the elaborate methods for grounding the apparatus and the anæsthetists and have relied upon a very high degree of cleanliness of the apparatus to guard against such accidents. At our suggestion, an investigation of the explosive possibilities was undertaken by Professor C. C. Meloche of the Department of Chemistry. This investigation is still incomplete and no formal report has been made.

At the present time Professor Meloche is still investigating the possible explosive qualities of cleanings obtained from various parts of the apparatus.

This material, which was collected for him by Miss Davis, is described as a "greasy, highly carbonaceous, copper containing material." This he separated from the oil by use of a centrifuge and washing with ether. It was then dried over an electric oven at 100° for one hour and experiments were then begun on its explosive qualities. Unfortunately the experimenter allowed the heat of the apparatus grossly to exceed that which was contemplated and a violent explosion took place, wrecking the apparatus though fortunately doing little damage to the experimenter. This apparently somewhat discouraged the investigator and the problem is still under discussion.

While of course no conclusions would be warranted from these observations, it is at least suggested that meticulous care in cleaning all parts of the apparatus is of first-class importance. We shall hope to make further report on this subject later.

SUMMARY

Our experience with ethylene as an anæsthetic appears to us to justify the following conclusions:

As an anæsthetic it has all of the advantages of nitrous oxide and oxygen and also gives greater relaxation and avoids objectionable cyanosis. It appears to be remarkably free from danger except that possibly resulting from explosions. It will not give complete muscular relaxation particularly for operations in the upper abdomen, and if this is required, it must be combined with local or regional anæsthesia or another anæsthetic selected. In our practice it has practically pushed nitrous oxide from the field and will, we believe, for ordinary surgical practice, supersede it. It is not an anæsthetic which can be employed except where trained anæsthetists are on hand and a rather cumbersome apparatus is available. It is not likely, therefore, to supersede ether or chloroform for use outside of hospitals, but for general hospital practice, it has outstanding advantages.

BLOOD CHANGES UNDER ETHYLENE ANÆSTHESIA*

By Hugh H. Trout, M.D.
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A few months before the publication of the preliminary report on ethylene by Luckhardt and Carter,[1] our attention was called by Dr. Dean Lewis to the lowered rate of increase of blood sugar in dogs when using this then new anæsthetic.

Banting gave the first injection of insulin on January 10, 1922, but, its general employment did not take place for several years later. This was due both to the reluctance with which the medical profession accepted it, as well as to the difficulty of obtaining a standardized product. During this period, after the introduction of ethylene, and before the universal acceptance of insulin, we had nine cases of diabetes on whom ethylene was employed for surgical complications. In seven of these cases there was a temporary rise of about 50 per cent. in the blood sugar, while, with two, there was a 10 per cent. decrease. The blood sugar in all nine cases returned in twenty-four hours to what it had been before operation. We had no comparison of a blood sugar study of a similar series of cases operated on with ether as the anæsthetic. However, all nine of these cases reacted more satisfactorily as regards their diabetes than had been our experience when using ether in similar cases.

Of course, the general employment of insulin has made any anæsthetic now comparatively safe as far as blood sugar is concerned. However, if one anæsthetic produces fewer and less marked changes in the blood chemistry than another, then such an agent has a definite field in surgery, not only in the diabetic but also in any badly handicapped patient—not to mention the lessening of discomfort in the post-operative recovery of the average patient.

No study was made of the acid-base balance and none of the CO_2 combining power, for many reports have already been made on these changes with the various anæsthetics. Nor have we made any studies of the effects of anæsthetics on the blood-cells, for, there are so many factors, such as infection, secondary anæmia, etc., entering in this field, that it would be impossible to properly estimate such results. In passing, it is worthy of note that an increase of the leucocyte count can apparently be due to a diabetic acidosis independent of any infection.

This fact is proven by the number of such cases reported, and by two cases admitted to Jefferson Hospital, Roanoke, Virginia, on whom insulin, for one reason or another, had been omitted in a diabetic patient, with not only the resulting coma, but also with the development of a very high leucocyte count. With the giving of insulin, the coma cleared up, and the

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leucocyte count returned very promptly to normal. Of course, the clinical importance of this observation is too obvious to more than mention, especially if one recalls the abdominal pains sometimes associated with diabetic acidosis.

A few months ago we started making a comparative study of the blood of patients who were given ethylene-oxygen anæsthesia in comparison with the blood of patients on whom other anæsthetics were employed. The major part of this comparison has been with ether, though ether in combination with ethylene; chloroform; nitrous oxide-oxygen and regional (sacral) anæsthesia have been compared in a few cases.

The changes in (a) blood sugar, (b) bleeding time, (c) coagulation time and (d) native complement have been studied and ethylene-oxygen compared with the other anæsthetics above mentioned.

These changes in the blood were studied not only in patients but a comparison was also made in dogs.

In all the patients there were three specimens of blood obtained from each case. The first specimen being obtained several hours before the anæsthetic started and without any breakfast. All patients, however, had morphia, grain ⅛ with atropine grain 1/150 about fifteen minutes before anæsthetic started. The second specimen procured just before the anæsthetic was discontinued. The third specimen acquired twenty-four hours after cessation of the anæsthetic.

In the ethylene group there were 100 patients who were given nothing except ethylene-oxygen. The average length of time for this group was thirty-six minutes, while the average increased percentage of blood sugar was 29 per cent. for first post-operative specimen, or .8 per cent. per minute.

With fifty-three ether cases the average length of time was forty-eight minutes, while the average increased percentage of blood sugar for the first post-operative specimen was 73 per cent. or 1.51 per cent. per minute.

From this it is seen ether increased blood sugar 46 per cent. more than ethylene per minute for the first post-operative specimen. In twenty-four hours, the blood sugar in both series returned to practically the same as it was pre-operatively.

With dogs this increase of blood sugar was even more marked with those animals taking ether. Briefly the average increase percentage of the first post-anæsthetic specimen was 185 per cent. greater with ether than with ethylene.

In 1924, Leake and Hertzman [2] experimenting with dogs, "found the changes in the blood sugar and alkali reserve in dogs under ethylene-oxygen anæsthesia much less in rate and degree than with either chloroform or ether."

From this comparison between the results on dogs and on human beings, it is seen this is but another illustration of the well-known fact too much reliance cannot be placed on animal experimentation. However, ether increased the blood sugar more than ethylene in both patients and dogs.

There is a rather general impression found amongst surgeons that both the coagulation and bleeding time is slightly, but temporarily, increased by

ethylene. Luckhardt and Lewis [3] thought *perhaps* oozing was a little more marked with ethylene than with other anæsthetics. In our series in both human beings and dogs this has not been found to be true. In fact, the average increase in patients per cent. per minute of ether over ethylene, as regards coagulation time, is 125 per cent. With dogs this was less marked, for, the average increase per cent. per minute of ether over ethylene was 110.4 per cent.

With bleeding time the percentage of ethylene decrease per minute over ether is .0014 per cent. in patients; while with dogs it was 3.8 per cent.

Straus and Rubin [4] concluded in their recent article on this subject:

"1. In twenty-five patients we found a definite decrease in the coagulation time during and shortly following the administration of ethylene anæsthesia.

"2. This decrease was short-lived. In most instances within twenty-four hours there was a return of the coagulation time to that noted before the introduction of narcosis.

"3. The bleeding time was also decreased."

Allen and Murray [5] do not believe from their observations of 2750 cases of ethylene anæsthesia, that the bleeding time is increased, though, they did not report any definite estimates. J. S. Horsley, Jr.,[6] in twenty-five consecutive ethylene anæsthesia cases made estimates of the coagulation time, before operation, at the close of operation, and seventy-two hours following operation, and came to the conclusion that coagulation time was not prolonged.

It is perfectly possible the cutaneous oozing which some surgeons believe is occasionally present with ethylene, might be due to the momentary cyanosis produced by the anæsthetist attempting to obtain relaxation just as the operation starts.

Deductions made from a study of the so-called native complement indicates there is less disturbance to this indicator of resistance with ether than with ethylene. This holds true both in the human being as well as dogs.

A detailed laboratory report follows this summary, though, of course, even in such a report many tables are necessarily omitted.

The following is a report of experimental work done by the laboratory staff of the Jefferson Hospital in 167 cases, to determine the effect of ether, ethylene and in a few instances other anæsthetics, on blood sugar, coagulation time, bleeding time and native complement.

The technic of Folin and Wu for blood sugars was used. This consisted in using the protein-free blood filtrate, alkaline copper solution, boiling six minutes, cooling, the addition of phosphomolybdic acid and distilled water, after which estimations are made in the Kober Colorimeter.

For coagulation time Howell's method was employed (4 to 5 c.c. of blood are withdrawn from a vein of the forearm, expelled at once into a clean glass tube and slightly tilted.) Coagulation time is that period elapsing between the time of withdrawal and the time when the clot is sufficiently formed to allow the tube to be inverted.

For bleeding time, Duke's method was used. This consists in cleaning

the finger with alcohol and then with a dry, sterile sponge. The finger is then punctured with a lancet and the time taken after the first drop is wiped away until bleeding ceases. Each drop as formed is absorbed with a piece of filter paper.

Complement, one of the indicators of resistance, was also studied. Titrations were made on each serum under the same conditions and at the same time. We began with .01 c.c. of serum, increasing to .08 c.c., or in some cases to .1 c.c. 5 c.c. of physiological salt solution, followed by the same amount of a 1 per cent. cell suspension were then added. The latter had been previously sensitized with an anti-sheep hæmolytic amboceptor. Normally there should be sufficient complement in .01 to .02 c.c. of serum to produce a complete hæmolysis of the sheep cells.

Patients were grouped according to anæsthetic, operation and the time in which anæsthesia was employed.

There were 100 patients having ethylene, 53 having ether, 8 regional, 1 N_2O and ether, 2 chloroform, 1 N_2O and ethylene.

The following is a summary of our findings, details of which will be found grouped separately and of which a second report is being made:

CASES IN WHICH ETHER AND ETHYLENE ANÆSTHETICS WERE EMPLOYED AVERAGED AS FOLLOWS:

Blood sugar	Ether	Ethylene
Average time	48 minutes	36 minutes
Average pre-operative	129 mgms.	140 mgms. Diabetics included
Average first post-operative	217 mgms.	182 mgms.
Average second post-operative	130 mgms.	142 mgms.
Average increase, first post-operative	88 mgms.	38 mgms.
Average percentage increase, first post-operative.	73%	29%
Average increase, second post-operative	1 mgm.	2 mgms.
Average percentage increase, second post-operative	.8%	1.4%
Average increase per minute, first post-operative.	1.51%	.8%
Average percentage increase of ether over ethylene of		.71 or 46%

It may readily be seen that the second post-operative estimations were practically the same as the pre-operative findings, neither anæsthetic appearing to alter the blood sugar to any marked extent twenty-four hours after operation.

Coagulation time	Ether	Ethylene
Average time	48 minutes	36 minutes
First post-operative, total increase	4½ minutes	5 minutes
First post-operative, average increase	.08 minutes	.05 minutes
First post-operative, average increase per minute	.0016	.0013
First post-operative, average increase per minute in seconds	.09	.04

First post-operative increase, coagulation time, per minute of ether over ethylene is thus 125 per cent.

Coagulation time	Ether	Ethylene
Second post-operative, total increase	11½ minutes	20 minutes
Second post-operative, average increase	.21 minutes	.2 minutes
Second post-operative, average increase per minute	.0043	.0055
Second post-operative, average increase per minute in seconds	.25 seconds	.33 seconds

Therefore second post-operative increase of coagulation time in ethylene over ether is 32 per cent.

Bleeding time	Ether	Ethylene
Average time	48 minutes	36 minutes
Total increase, 1st, post-operative	5.5 minutes	7.75 minutes
Average increase, 1st, post-operative	.103 minutes	.1175 minutes
Average increase per minute, first post-operative	.0021	.0021
Average increase per minute, first post-operative	.126 seconds	.126 seconds
Average percentage, increase per minute, first post-operative	.463%	.405%

Therefore there is a first post-operative average percentage increase per minute of ether over ethylene of .0014 per cent.

It may thus be seen that there was no practical increase from the standpoint of bleeding time in the first post-operative findings.

Bleeding time	Ether %	Ethylene %
Increase second post-operative	70	6.75
Average percentage increase, second post-operative	1.32	6.75
Average percentage increase per minute	.027	.187

Therefore, it may be seen from the above that there was a percentage increase in bleeding time of .85 of 1 per cent. per minute of ethylene over ether.

Complement.—For the first post-operative there was an average increase per minute under ethylene of .834 per cent. Ether showed a percentage average increase per minute of .7 of 1 per cent. It may be seen, therefore, that there is practically no difference in complement, though the balance of .1 of 1 per cent. is slightly in favor of ether.

In the second post-operative complements the average increase per cent. for ethylene per minute was .423 per cent., while for ether it is .135.

False conclusions from the above might be drawn that ether was better from the standpoint of complement by 21 per cent., though the type of operation, necessary shock following same, etc., plays a great part in the above percentages.

A similar study to show the comparative values of ethylene and ether was made on each of ten adult dogs. The animals were first anæsthetized with ethylene, held in this state of anæsthesia for twenty minutes, after which they were allowed to revive. Blood sugars, coagulation times and bleeding times were taken under identically the same conditions as in the first portion of this report concerning the human patients. The same animals were then allowed to rest for a week, at the end of which time they were again anæsthetized for a like period of time with ether anæsthetic and the same observations were made.

Blood sugar	Ether	Ethylene
Average time	20 minutes	20 minutes
Average pre-anæsthetic	131 mgms.	110 mgms.
Average first post-anæsthetic	236 mgms.	141 mgms.
Average increase, first post-anæsthetic	105 mgms.	31 mgms.
Average increase percentage first post-anæsthetic	80%	28%

The average first post-anæsthetic increase of ether over ethylene was 21 mgms., average increase percentage first post-anæsthetic, either over ethylene, 185 per cent.

Blood sugar	Ether	Ethylene
Average second post-anæsthetic	143 mgms.	95 mgms.
Average increase second post-anæsthetic	12 mgms.	Decrease 15.5 mgms.
Average increase per minute, second post-anæsthetic	.655	Decrease .775 mgms.
Average percentage increase per minute, second post-anæsthetic	.91%	Decrease .7%

Therefore the average decrease of ethylene percentage over ether percentage is 1.61 per cent. The average decrease of ethylene over ether per minute is .8 per cent., and the average per cent. decrease of ethylene over ether is 23 per cent.

Coagulation time	Ether	Ethylene
Average pre-anæsthetic	1.15 minutes	.95 minutes
Average first post-anæsthetic	1.7 minutes	.90 minutes
Average second post-anæsthetic	1.37 minutes	.8 minutes
Average percentage increase, first post-anæsthetic	48%	Decrease 5%
Average increase per minute, first post-anæsthetic	2.4%	Decrease .25%
Average percentage increase, second post-anæsthetic	1.9%	Decrease 15%
Average percentage increase per minute	.95%	Decrease .75%

The ether average *percentage* increase per minute over ethylene average decrease percentage per minute is 2.65 per cent., and the average increase per cent. per minute ether over ethylene is 110.4 per cent.

In the second post-anæsthetic, the ether average increase per minute over ethylene is 1.7 per cent. The *percentage* increase, therefore, of ether over ethylene per minute is 178 per cent.

Bleeding time	Ether	Ethylene
Average pre-anæsthetic	1.27 minutes	1.2 minutes
Average first post-anæsthetic	.925 minutes	.6 minutes
Average second post-anæsthetic	.110 minutes	1 minute
Average percentage decrease, first post-anæsthetic	27%	48%
Average percentage decrease, per minute, first post-anæsthetic	1.3%	2.4%
Average percentage decrease, second post-anæsthetic	13%	16%
Average percentage decrease per minute, second post-anæsthetic	6.5%	.8%

The decrease per cent. ethylene was 21 per cent. The ethylene decrease per cent. per minute was 1.05 per cent. The percentage of ethylene decrease over ether decrease is 77 per cent. and the percentage of ethylene decrease per minute over ether decrease is 3.8 per cent.

Complement	Ether	Ethylene
Average time	20 minutes	20 minutes
Average pre-anæsthetic	.047	.042
Average first post-anæsthetic	.049	.047
Average second post-anæsthetic	.048	.048
Average percentage increase, first post-anæsthetic	.42%	1.19%
Average percentage increase, first post-anæsthetic, per minute	.021%	.059%
Average percentage increase, second post-anæsthetic	.28%	1.428%
Average percentage increase, second post-anæsthetic per minute	.014%	.0714%

Average per cent. increase of first post-anæsthetic, ethylene over ether, 183 per cent. Average increase second post-anæsthetic, ethylene percentage over ether percentage, .057 per cent. Average percentage increase, second post-anæsthetic, ethylene over ether, 407 per cent.

The following is a summary of the average increases and decreases of the various other anæsthetics which were used in our human cases, as compared to ethylene. The tests were run in identically the same manner and under the same conditions as those mentioned under ether and ethylene alone.

ETHYLENE AND ETHER

Blood sugar.

First post-operative-average increase per cent. per minute	.5%
Second post-operative-average increase per cent. per minute	.7%
First post-operative-average increase per cent. of ethylene over ethylene and ether	.3%
Second post-operative-average decrease per cent. of ethylene over ethylene and ether	.68%

Coagulation time.

First post-operative-average decrease per minute	.05 or .06%
Second post-operative-average increase per minute	.001 or .03%
First post-operative-average increase ethylene over ethylene and ether	.0513 or 590%
Second post-operative-average increase ethylene over ethylene and ether	.004 or 400%

Bleeding time.

First post-operative-average increase per minute	.001 or .3%
Second post-operative-average decrease per minute	.001 or .3%
First post-operative-average per cent. increase per minute, ethylene over ethylene and ether	.15 or 37%
Second post-operative-average per cent. increased per minute, ethylene over ethylene and ether	.4 or 213%

Complement.

First post-operative-average increase per minute	.33%
Second post-operative-average increase per minute	.01%
First post-operative-average per cent. increase per minute of ethylene and ether over ethylene of	.271%
Second post-operative-average per cent. increase per minute of ethylene over ethylene and ether of	.0614%

REGIONAL

Blood sugar.

First post-operative-average increase per minute	1.04 mg. or 173%
Second post-operative-average increase per minute	.16 or .11%
First post-operative-average increase per minute, ethylene over regional	.01 or .07%
Second post-operative-average increase per minute, regional over ethylene	.105 or .72%

Coagulation time.

First post-operative-total decrease	3.5 minutes or 74%
First post-operative total increase	2 minutes or 95%
First post-operative-total decrease	1.5 minutes, or increase total 21%

First post-operative-average decrease per minute	.044 or inc. .026%
Second post-operative-average increase per minute	.0045 or 49%
First post-operative-average decrease per cent. per minute, regional over ethylene	.074%
Second post-operative-average decrease per cent. per minute, regional over ethylene	1.02%

Bleeding time.

First post-operative-average increase per minute	none
Second post-operative-average increase per minute	none
First post-operative-average decrease per minute, regional over ethylene	.405%
Second post-operative-average decrease per minute, regional over ethylene	.18%

Complement.

First post-operative-average increase per minute	.0023 or 1.672% (no decrease)
Second post-operative-average increase per minute	.00029 or 2.65%
First post-operative-average increase per minute, regional over ethylene	.838%
Second post-operative-average increase per minute, regional over ethylene	2.227%

SUMMARY

Finally we believe ethylene-oxygen anæsthesia produces: (a) Less alteration of the percentage of blood sugar, no appreciable change in either; (b) the coagulation time, or (c) the bleeding time, and (d) only a slight disturbance of the native complement when compared with any other of the now commonly employed anæsthetics. However, the whole study of blood changes under any anæsthetic is apparently dependent on the amount of oxygen in the circulation therefore, the anæsthetic chosen for the individual case should be the one that gives less cyanosis with a comfortable relaxation and does this in that particular hospital where it is to be employed.

I am gratefully indebted to Dr. K. T. Redfield and his assistants for all the laboratory work, and to Dr. J. W. Sayre and Miss Florence Barnett for their assistance with the various anæsthetics.

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ANÆSTHESIA IN GENITO-URINARY OPERATIONS*

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A special technic for securing the type of anæsthesia best suited for regional operations has developed together with the technic of the performance of such operations. In the field of genito-urinary surgery, in particular, it has been found that a general inhalation anæsthesia is not the anæsthetic method of choice, since in most cases there is either a functional impairment or some pathological condition of the kidney.

Since the discovery in 1900 by Kaplan that the sacral canal could be used for the production of anæsthesia, and the successful utilization of this method by Stoeckel in 1909, the use of sacral anæsthesia has been extensively advocated, for genito-urinary operations in particular, as has spinal anæsthesia since its first application by Corning in 1885. Each of these methods has its ardent advocates, advocates who in too many instances urge the use of one or the other of these measures as being adapted to practically every type of operation, especially in the pelvic region.

The prime purpose of this paper is to deprecate the application of any one method of anæsthesia to the exclusion of other methods, whatever the type of operation to be performed; and on the other hand, to propose that the anæsthetic method be strictly individualized, that is, that it be adapted in every case to the psychic and physical condition of the patient as well as to the anatomical possibilities of the case. Perhaps in no other group of cases is this need for strict individualization more emphatically needed, for the genito-urinary surgeon deals with every type of individual at every age, and because of the peculiar nature of diseases within the genito-urinary tract the psychic factor is usually prominent, if not predominant. The comparatively young man with stricture, the woman with persistent cystitis, and the old man with an enlarged prostate and resultant retention, each has a high degree of nervous irritability which must be recognized as a serious factor in any surgical procedure. The mere overcoming of pain caused by the trauma of local nerves, therefore, is not sufficient; such pain, in fact, might be far less harmful than psychic distress.

It follows that the principle of anoci-association should be applied in these, as in operations in which a combination of methods is more generally applied, such, for example, as operations for exophthalmic goitre, and operations on the stomach or gall-bladder, etc.; that is, in each individual case we should employ such a combination of anæsthetic and operative methods as will minimize both psychic and traumatic shock.

* Read before the American Surgical Association, May 13, 1927.

In addition to the general objections to the lipoid solvent anæsthetics, it should be borne in mind that, as we have already mentioned, inhalation anæsthetics have a special effect upon the kidneys. Albuminuria follows inhalation anæsthesia with ether in about one-fourth of the cases and casts are frequently found in the urine. Provided the kidneys are sound, the irritation produced by ether or chloroform usually disappears in a short time, but in patients in whom the kidneys are already diseased the effect of the inhalation anæsthesia may be sufficient to produce a fatal suppression of the urine or an intractible albuminuria. Moreover, as stated by Sollmann,[1] experimental studies have shown that the kidneys of old animals show greater histological and functional injury after anæsthesia with ether and chloroform than do those of younger animals, this often being the case even in animals in which the kidney function before operation appeared to be normal.

Sollmann has found that the functional capacity of the kidneys, as measured by the phenolsulphonephthalein test, is somewhat decreased by ether anæsthesia, this effect being in direct relation to the duration of the anæsthesia. It would appear, therefore, unnecessary even to try to offer any argument in favor of anæsthesia with ether in operations which affect the kidneys. In operations upon the bladder for carcinoma or in operations upon the prostate, when the vitality of the patient is usually diminished both by age and by urinary disturbances, inhalation anæsthetics are contra-indicated because of their effects upon the cells of the central nervous system. As Crile's researches have shown, ether anæsthesia of itself alone contributes directly to the production of shock.

The choice, therefore, of anæsthetic methods in genito-urinary surgery must lie among nitrous oxide oxygen analgesia, ethylene gas, spinal anæsthesia, sacral anæsthesia, and local anæsthesia. In analgesia produced by nitrous oxide oxygen a sufficient degree of relaxation is rarely obtained. While nitrous oxide oxygen analgesia may be used as an adjuvant, some other method of anæsthesia is required, therefore, and our choice is further reduced to spinal, sacral or local anæsthesia.

Among the latter, according to my own experience, spinal anæsthesia is most hazardous because of its effect upon the blood-pressure. I know that my judgment in this regard is not in accord with that of many other operators. Rytina,[2] in particular, offers in favor of spinal anæsthesia a series of 73 prostatectomies with but one death and no permanent complications; only one operation in this series was performed in two stages. Although Rytina's judgment seems to be confirmed by that of other writers, nevertheless, for ourselves we place our chief reliance upon sacral block and local infiltration for suprapubic and scrotal operations, and upon regional nerve block, local infiltration, and nitrous oxide oxygen analgesia for operations upon the kidney.

In operations upon the kidney it should be borne in mind that although

the approach is through tissues which are not as fully endowed with afferent nerves as are the tissues of the anterior abdominal wall, nevertheless there are a sufficient number of nerve-endings in the skin and muscles to make their infiltration advisable. I have used local infiltration and a paravertebral block for nephrectomy in a number of cases, and the only case in which the patient complained of pain was one in which the kidney was inflamed and adherent to the peritoneum, so that the separation of the adhesions was very difficult.

In operations below the kidney, however, that is, on the bladder and the prostate, a sacral block is employed, the technic which we use being the same as that which has been carefully described by Hunt.[3] A one per cent. solution of novocain combined with 6 minims of a 1/1000 solution of adrenalin is injected through the sacrococcygeal membrane into the caudal canal, the insertion of the needle being preceded by progressive anæsthetization of the path to the caudal canal. Occasionally this is followed by injections through the second, third and fourth sacral foramina on each side. After these injections have been made, the patient is turned over and a complete regional block of the abdominal wall is made. The anæsthesia obtained by this method lasts for an hour or more, complete relaxation is secured, and the operation is painless.

If the operation is carried to the bladder, the wall of the bladder is infiltrated with a ¾ per cent. solution of novocain. If the prostate is to be removed, then the novocain is infiltrated between the gland and the capsule, as this helps to separate the prostate from the capsule. Sacral anæsthesia, therefore, is of value in all operations upon the bladder and prostate—the removal of a diverticulum of the bladder, the removal of bladder stone, resection of the bladder and prostatectomy.

In all cases, however, and this is a point upon which we lay special stress, if the patient is at all apprehensive, the anæsthetist is prepared to administer nitrous oxide oxygen until the stage of analgesia is reached. Apprehension and nervous irritability on the part of the patient may contribute to shock, and the post-operative condition of the patient will be so much the less favorable, however successful the operation may be from a technical standpoint. For the same reason, before the operation each patient receives a dose of morphin, gr. 1/6 to ¼, and atropin, gr. 1/150. The value of the trained anæsthetist is never more strikingly illustrated than in these cases. It is true that the injection of the local anæsthetic, whether it be administered sacrally or regionally, is in the hands of the surgeon; but the anæsthetist, sitting at the patient's head, bathes his head and wets his lips, and is ready to administer nitrous oxide oxygen if the nervous condition of the patient demands it. No local anæsthesia is successful if the patient complains of pain and discomfort, even though he is persuaded or coerced into tolerating the operation. A nervous, apprehensive woman will frequently request inhalation anæsthesia, and if the request is urgent it should never be denied.

Frequently after the first administration of nitrous oxid-oxygen the degree of anæsthesia may be lessened, and the patient may finally come out from the stage of analgesia and yet, on account of the complete regional or sacral block, be practically unconscious of what is going on.

Another advantage in the use of sacral anæsthesia lies in the fact that the patient is entirely conscious after the operation and suffers no ill effects such as nausea, etc. The man from whom a prostate has been removed under sacral anæsthesia is often greatly stimulated and encouraged by being permitted to eat a light breakfast or to drink coffee or tea as soon as he has returned to the ward. He may have been conscious throughout the operation and though he has felt no pain, may have been apprehensive because of the fact that an extensive and dangerous operation was being performed, but the immediate assurance that he may eat lightly or take a drink at once often has an astonishing effect upon his morale, and he feels that after all the operation could not have been as serious as he feared.

Not only in the operating room but in the examining room of the genito-urinary surgeon, anæsthetic methods must be considered. For internal urethrotomy novocain is used, never cocain, for the danger of poisoning is too great, even with weak solutions. I have seen severe collapse follow the use of cocain. For cystoscopy, ordinarily an injection of 10 c.c. of a two to four per cent. novocain solution into the urethra suffices, but if the patient is very sensitive and no pyelogram is to be made, a hypodermic injection of morphin and atropin is given in addition. If a pyelogram is to be taken, however, it is usually unwise to give morphin, as the patient should retain sufficient sensibility to pain to be able to tell the operator when distention of the renal pelvis by the injected solution begins to produce pressure. The possibility that morphin may produce vomiting also contra-indicates its use when a pyelogram is to be taken.

In cases of tuberculosis of the bladder, when the bladder is small and contracted, sacral anæsthesia is the anæsthetic method of choice, for by its aid a cystoscopic examination can generally be made without causing any discomfort to the patient. For punch cases, sacral anæsthesia is contra-indicated and local infiltration of the bladder neck, together with nitrous oxide oxygen analgesia is used. This is essential because of the complete relaxation of the internal sphincter which is sometimes produced by the sacral block.

I believe that in no group of cases has the use of the sacral block and regional anæsthesia proved to be of greater value than in old men with enlarged prostates. This type of case in the past presented some of the greatest hazards in surgery. Renal insufficiency, with the danger that any further suppression of the action of the kidneys may produce acute uræmia and death, makes the use of general inhalation anæsthesia a serious menace. The lowered blood-pressure which is often produced by spinal anæsthesia is likewise disconcerting. In such cases as these, however, sacral anæsthesia

has made it possible to extend the possibility of operation until practically no patient need be refused the chance of added comfortable years which can be given by the removal of the prostate.

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THE ANÆSTHETIC PREFERENCES OF AMERICAN SURGEONS

COMPILED FROM REPORTS RECEIVED FROM SIX HUNDRED AND FORTY SURGEONS

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Some time ago the writer undertook to review some of the recent literature on anæsthesia. This study very soon led to a bewildering mass of arguments, each for the most part extolling the virtues of some particular anæsthetic or some method of giving an anæsthetic. Also, a not too critical analysis of the arguments presented might have seemed to have indicated the possibility that such an old stand-by as ether had already been, or very soon would be, very largely displaced by some of the newer anæsthetics.

In order to clear my mind on the subject I decided to obtain as near as possible a composite picture of the judgments of a representative group of American surgeons as shown by their choice of anæsthetics for several typical types of operations. To obtain the necessary data the following questionnaire was sent to approximately 1000 Fellows of the American College of Surgeons:

"I am desirous of ascertaining the present preferences of a considerable number of representative American surgeons as regards means of producing surgical anæsthesia. I will, therefore, greatly appreciate the favor if you will answer the following questions and return the same in the enclosed addressed envelope:

"1. What anæsthetic do you use as a rule in laparotomies in the average run of good risk cases?

"2. What anæsthetic do you use as a rule in laparotomies in cases comprising the poor risk group?

"3. What anæsthetic or anæsthetics do you generally use in inguinal hernia operations?

"4. What anæsthetic or anæsthetics do you ordinarily use in goitre operations?

"5. What anæsthetic do you ordinarily use when called upon to use anæsthesia in fracture cases?

"6. Do you use spinal anæsthesia? If so, in what class of cases do you use it?

"Any comments regarding your views as to the use of anæsthetics will be much appreciated. A summary of the answers received will be sent to all surgeons answering this questionnaire."

The selection of names was made at random, six or seven names to the page from those registered as surgeons or gynecologists in the 1926 year book of the College.

Six hundred and forty replies were received. The answers to questions Nos. 1 to 5 are summarized in Table I. The numbers in the several columns of the table do not exactly correspond with the number of replies received. This is because a few surgeons in answering one or more questions report equal preference for two anæsthetics. If so, both anæsthetics are given

equal credit. In the case of fractures and goitres a few surgeons report that they do not treat these cases at all. The additions and subtractions due to the reasons just enumerated are so few in number as to have no noteworthy effect on the figures presented.

From the answers to the first question, it is evident that for operations of the type of the average run of laparotomies 555 out of 657 use ether, alone or rely largely on ether after a primary anæsthesia started with some other of the volatile anæsthetics. One-half of all the surgeons and approximately 60 per cent. of the ether-using surgeons use straight ether. Of the

TABLE I

Summary of Answers

Question No.	I.	II.	III.	IV.	V.
Ether	329	113	195	113	249
Nitrous oxide-ether sequence	198	106	85	45	109
Nitrous oxide-oxygen	28	87	27	55	109
Nitrous oxide-ethylene	8	8	0	5	6
Ethylene	33	51	32	35	35
Ethylene plus ether or ethylene-ether sequence	25	8	4	3	9
Ethyl chloride	0	0	0	0	1
Ethyl chloride-ether sequence	3	0	2	1	9
Ethyl chloride-ethylene sequence	0	1	0	0	0
Chloroform	1	0	1	0	3
Local—including regional and paravertebral	5	113	255	147	4
Local—ether	4	30	20	26	0
Local—gas oxygen	13	110	27	118	0
Local—gas oxygen-ether	4	1	0	1	0
Local—ethylene	5	28	5	15	2
Spinal	2	17	7	0	0
Colonic ether and oil	0	0	0	6	0

reporting surgeons who start with some other anæsthetic and switch to ether, the great majority use the nitrous oxide-ether sequence, a few use ethylene plus ether and three surgeons use the ethyl-chloride-ether sequence.

Thirty-three, or 5 per cent., of the reporting surgeons use ethylene, 4 per cent. use nitrous oxide and oxygen and just over 1 per cent., ethylene and nitrous oxide.

Three surgeons report that they do their ordinary laparotomies under local anæsthesia, two use paravertebral, one uses ether or spinal and 25, or 4 per cent., use local plus one or the other of the volatile anæsthetics. Only one surgeon out of the 640 mentions the use of chloroform for laparotomies.

The outstanding fact in the answers to Question 1 is that approximately 85 per cent. of 640 surgeons scattered all over the United States use ether as their standard anæsthetic in operations of the type of the average laparotomy. As the human animal is constituted, this is about as near a unanimous verdict as is ever obtained from scattered individuals.

The answers to Question 2 show a wide diversity of opinions and prac-

tices. Because some of the surgeons use more than one method, 672 methods are recorded for 640 answering surgeons. Two hundred and sixteen of the 329, or practically two-thirds of the straight ether users, abandon ether and shift to some other form of anæsthesia. Likewise, 112 of the 226 ether-sequence users abandon ether.

Of the total shifts, 18 (5 per cent.) go to ethylene, 59 (17 per cent.) go to gas-oxygen, 110 (33 per cent.) go to straight local and 143 (42 per cent.) go to local and some volatile anæsthetic, chiefly gas-oxygen, and 16 (5 per cent.) shift to spinal anæsthesia.

Altogether approximately one-half of the reporting surgeons state that they use a different method of anæsthesia when operating on poor risk laparotomy cases from that used for ordinary major operations. This shift is practically entirely away from ether. Although an analysis of the individual answers and comments shows a great deal of uncertainty on the part of individual surgeons as to what choice of anæsthetic they should make, it is interesting and possibly highly significant that 72 per cent. or approximately three-quarters of the shifts are to local anæsthesia, or local reinforced if necessary with one of the volatile anæsthetics.

Question 3 was inserted because it covers a rather typical example of a common operation performed by all surgeons and one requiring no very special relaxation but nevertheless each operation covering an appreciable period of time. Again, we find almost half (44 per cent.) of the reporting surgeons using a different form of anæsthesia from the one they use in the average run of laparotomies. In this case, however, the shift is not from ether alone but from all forms of volatile anæsthetics and once the surgeons have decided to make a shift, there seems to be but little question as to their choice. Two hundred and fifty, or 88 per cent., go to straight local, 26, or an additional 9 per cent., of those shifting go to local reinforced if necessary with one of the volatile anæsthetics. Seven use spinal anæsthesia.

Although local anæsthesia is very popular in hernia operations, the surgeons using some form of local anæsthesia for hernia operations comprise less than half (47 per cent.) of the total. Forty-three per cent. use some form of ether anæsthesia.

The answers to Question 4 show that in goitre operations more than half of the ether users shift to some anæsthetic other than ether. This shift is chiefly to local anæsthesia and local plus nitrous oxide and oxygen, although a few have changed to nitrous oxide and oxygen, and we also find two more surgeons using ethylene than use ethylene for the average run of laparotomies. In goitre operations we also find a form of anæsthesia not mentioned in the answers to the previous questions, namely, colonic ether and oil anæsthesia used by six surgeons.

The answers to Question 5 show a moderate shift from ether, although 376 (70 per cent.) of the 536 surgeons answering this questionnaire use some form of ether anæsthesia when an anæsthetic is necessary for the reduction of fractures. One hundred and nine (18 per cent.) surgeons use nitrous

oxide and oxygen. In this group we find two anæsthetics scarcely mentioned previously. Sixteen surgeons state that they use "light chloroform" anæsthesia and one surgeon uses ethyl chloride.

The practically complete abandonment of chloroform as an anæsthetic used in major anæsthesia is probably the most important change in the use of the volatile anæsthetics which has taken place during the past twenty-five years. However, judging from comments relative to chloroform, it is quite evident that a number of the surgeons answering the questionnaire feel that owing to one or more court decisions and some adverse criticisms, chloroform has at present a far worse reputation than it deserves.

Question 6 concerning the use of spinal anæsthesia was answered by 622 surgeons. Of those answering 419 (67 per cent.) state definitely that they do not use spinal anæsthesia. A considerable number of those not now using spinal anæsthesia state that they did formerly but have abandoned its use for one reason or another. One surgeon states that after an experience of 1056 cases he abandoned spinal anæsthesia because of the headaches which he was unable to avoid. Several state that they now use caudal and sacral anæsthesia in the cases in which they formerly used spinal anæsthesia. Approximately 90 per cent. of those who use spinal anæsthesia state definitely that they use it only occasionally in special types of bad risk cases. Most surgeons specified definitely the conditions under which they employed this form of anæsthesia. Eighty surgeons mentioned prostates; 41, amputations of lower extremities; 22, pelvic and vaginal work; 16, "poor risks"; 21, hemorrhoids and rectal work; 13, diabetes; 12, operations below the diaphragm; 10, severe injuries of lower extremities; 9, senile gangrene and old people; 4, bladder and genito-urinary; 4, cardiac cases; 3, fractures; and one surgeon mentioned intestinal obstruction.

The problems associated with anæsthesia have been constantly before each individual surgeon from before his first operation up to the present time. A surgeon's views on anæsthesia are usually the product of a long series of objective experiences and the deductions drawn therefrom. It is, therefore, not surprising that nearly half of the answering surgeons took the opportunity to comment in a definite and forceful manner regarding their views as to the use of anæsthetics. While from their very nature these highly individualistic expressions of opinion often reflecting the personalities of the writers cannot be summarized in statistical terms, it is possible to classify the general trend of these comments under several different headings.

Ether.—A very considerable number of the ether users state that they have from time to time tried one or more or all of the other volatile anæsthetics but for one reason or another have been forced to the conclusion that all factors considered, ether is the one safest anæsthetic. Many of these surgeons emphasize their point by stating their belief that if the same amount of skill and care is given to an ether anæsthesia as is mandatory in other forms of anæsthesia most of the objections to ether are largely elimi-

nated. Others emphasize the advantages of the complete relaxation attainable under ether.

Nitrous Oxide.—All seem to be agreed that the safety and usefulness of gas-oxygen as a major anæsthetic is dependent upon the skill and experience of the anæsthetist. The most numerous and most enthusiastic commenters on nitrous oxide are those who use gas oxygen in conjunction with local anæsthesia in both laparotomies and goitres. A number of former gas-oxygen users state that they are now using ethylene.

Ethylene.—Many of the ethylene users are extremely enthusiastic over its use. Several report three years' continuous use with no accidents or untoward results of any kind. On the other hand, some state that to get satisfactory relaxation they have to add ether or local infiltration in a considerable portion of cases. Several mention excessive bleeding from the smaller vessels under ethylene. Several mention the cost, saying that they can afford to use it only with their more well-to-do patients. Several have given up the use of ethylene because of the dangers of explosion which they think outweigh its advantages. Ethylene is at present used more or less extensively by approximately 10 per cent. of the surgeons answering the questionnaire.

Sacral and Caudal Anæsthesia.—Although sacral or caudal anæsthesia was not mentioned in the questionnaire, 69 (11 per cent.) of those answering the questionnaire took the occasion to make favorable mention of this special form of regional anæsthesia. The comments were uniformly favorable and often decidedly enthusiastic. From the answers as returned, it would seem that over 10 per cent. of surgeons are at present using this form of anæsthesia for rectal, lower pelvic and bladder operations.

OBSERVATIONS ON THE EFFECT OF GLYCOSURIA IN SURGERY*

By Herbert A. Bruce, F.R.C.S. (Eng.)
Frederick Hipwell, M.D.
and
J. Winfield Rush, M.D.
of Toronto, Canada

A very different situation confronts the surgeon of to-day in respect to an operation upon a diabetic to that which existed but four short years ago. Faced with a mortality rate of 30 per cent., with frequent acidosis and infection and uncertain results, it cannot be wondered at if he approached such an operation with considerable misgiving. But all this has been changed since the discovery of insulin and the acquisition of more detailed and comprehensive knowledge of diet and the treatment of diabetes mellitus. Surgeons now undertake an operation upon a diabetic with as much confidence in the result as though he were not suffering from a natural insulin deficiency. Our cases are ninety-seven in number with two deaths, a mortality rate of 2.1 per cent. One patient had advanced carcinoma of the stomach and died two weeks after a gastro-enterostomy; the second was suffering from advanced diabetic gangrene and succumbed suddenly from a cardiac condition on the tenth day after operation.

While the number of operations performed upon diabetic patients has increased enormously, there has been comparatively little reference to the subject in the literature. Considering the broad phases of the subject, certain physiological features or theories should be kept in mind, particularly that diabetes mellitus is a profound disturbance of metabolism affecting primarily the carbohydrate mechanism.

The chemistry of the body is altered in such a manner, however, that carbohydrate metabolism is not affected alone. Protein and fat enter into the change very materially. For instance, we have observed that excessive fat decreases the glucose tolerance and tends to incite ketonic acidosis.

The effect of an anæsthetic upon a diabetic should be noted. We have observed a rapid rise from 100 to 300 mgs. of blood sugar during the administration of ether of average duration. This has occurred on more than one occasion in spite of insulin having been administered previous to operation. Further, it is known that on the administration of an anæsthetic the supply of stored glycogen is rapidly exhausted, probably causing the increase in blood sugar. These occurrences are more marked after ether anæsthesia than after gas oxygen. Infiltration anæsthesia introduces the possibility of devitilization of tissue in which the metabolism is already deranged, and may give

* Read before the American Surgical Association, May 14, 1927.

rise to sloughing. Regional anæsthesia in selected cases with or without supplementary gas oxygen is ideal and has given rise to no marked increase in blood sugar.

Several patients were fed diets high in carbohydrates with large amounts of insulin previous to operation. This was done that an excessive amount of glycogen might be stored. Clinically, however, these cases did not do better than those not so prepared. The probable explanation of this phenomenon is to be attributed to the effect of the anæsthetic upon stored glycogen.

In operating upon diabetics our procedure generally is as follows:

Where possible, a patient is kept under observation and treatment for sufficient time to render the urine clear of sugar and acetone, with a fasting blood sugar approximating normal. Diet is constructed so as to yield for the ordinary adult from 25 to 30 calories per kilo of body weight. Insulin is used where necessary and in sufficient amounts to accomplish this result.

On the day of operation, from two to three hours before administering the anæsthetic, the patient is given the usual dose of insulin for that time of the day. The glucose value of the meal is given in the form of orange juice and glucose. Following the operation a blood sugar is estimated, and if above 200 mgms. per 100 c.c., insulin is administered—the dose varying with the need demonstrated prior to operation. Close watch is kept on the blood sugar and the urine for the balance of the twenty-four hours. An attempt is made to keep the urine clear of sugar and acetone and the blood sugar no higher than 200 mgms. per 100 c.c. If the operation has been prolonged an interstitial is given of 2½ to 5 per cent. of glucose in normal saline. This is repeated as necessary. We do not encourage our patients to take quantities of fluid by mouth for the first twelve hours. Within twenty-four hours we try to have the patient ingesting food which consists for the most part of carbohydrate and protein in the same proportion as that contained in the diet previous to operation. Fats are intentionally allowed to fall as low as possible. Should there be any nausea or abdominal distress, we continue with interstitials of glucose and saline.

It is well known that infection or absorption from an infective focus disturbs materially the balance between insulin deficiency, insulin dosage and diet. The removal of a focus of infection would lead us to expect a decrease in the necessary insulin dosage. (*Vide* Cases I and IV.)

We have observed that healing of a wound will take place by first intention in the presence of a blood sugar somewhat above normal with the patient showing small amounts of sugar in the urine when no acetone is present. (*Vide* Cases II and IV.) It seems to us that the incomplete combustion or metabolism of fat plays more of a rôle in this connection than does increased blood sugar as pointed out by Woodyatt and others.

Types of diabetic patients met with by the surgeon readily group themselves into the following classes:

1st.—Those cases which require immediate surgical intervention, such as acute appendicitis, intestinal obstruction, hemorrhage, etc.

2nd.—Cases in which there is no urgency, but where surgery is considered the logical treatment, such as various gynæcological and plastic conditions.

3rd.—The complications of diabetes, such as carbuncle or diabetic gangrene.

4th.—That group of cases in which surgery is undertaken in the hope of improving the actual diabetic condition.

Emergency surgery allows no preparation whatever, but it is seldom that an operation cannot be delayed to make a blood sugar estimation. If the patient is known to be diabetic with definite increase in blood sugar content, insulin is administered previous to the operation, the amount given depending on the severity of the symptoms of diabetes. The after-treatment follows the same plan generally to that previously detailed, the difference being, however, that more insulin is used and we administer it every four hours with a blood sugar control. Within five to seven days there has been, in most instances, a return to the pre-operative diet and insulin dosage.

The following cases illustrate the classification we have made:

Case I.—M. S., age forty-three, female. Had been ailing for ten days with acute appendicitis when admitted to the hospital. A large tender mass could be made out in the right iliac region extending into the pelvis—clearly an appendiceal abscess. The skin was dry and the breath loaded with acetone. Urine contained 1.9 per cent. sugar and the blood sugar was 384 mgms. per hundred c.c. fasting. She also had a large soft bilateral enlargement of the thyroid with exophthalmos. Pulse 160.

Patient was given 15 units of insulin and operated upon the day following admission to the hospital. At operation we found a ruptured appendix and a mass of infiltrated tissue and pus surrounding this. It had infiltrated the wall of the cæcum, involved the right ovary and the right side of the uterus. Appendix and right ovary were removed and the cavity drained.

Patient did very well following operation. There was a good deal of purulent discharge from the wound. The diet consisted of carbohydrate 100 grams, protein 60 grams, and fat 100 grams. This amount of carbohydrate was thought advisable to combat the acidosis which was very severe. Insulin was increased 70 units per day and blood sugar estimations made twice daily. As the discharge cleared up insulin was reduced 10 units per day, because we were obtaining moderate hypoglycæmic reactions. The same diet was continued. The daily dose of insulin was determined by the amount of sugar in the previous twenty-four hours' urine. After two weeks the discharge had become non-purulent; the insulin was reduced to 10 units a day. The blood sugar was 156 mgms. There was no glycosuria. The following day insulin was discontinued, but there appeared a trace of sugar in the urine. This showed the carbohydrate tolerance to be less than 100 and as we had still to combat some acidosis, it was necessary to prescribe, indefinitely, 10 units of insulin per day.

Case II.—M. H., age forty-six, female. Patient has been diabetic for four years but was controlled with a diet consisting of 90 grams carbohydrate, 80 grams of protein, 120 grams of fat and from 40 to 45 units of insulin in two doses daily.

Persistent backache and metrorrhagia existed for several years due to uterine myomata.

Hysterectomy with removal of cystic right ovary was performed under ether anæsthesia.

Blood sugar fasting before operation was 117 mgms. per 100 c.c.

Blood sugar immediately after operation was 100 mgms. per 100 c.c.

Blood sugar ten hours after operation was 206 mgms. per 100 c.c.

She received twenty-five units of insulin two hours before operation and at the same time 200 c.c. orange juice with twenty grams glucose. Recovery was uneventful, with primary healing of the wound. While frequently sugar was found, ketone bodies occurred only in very small amount in the urine.

At the time of writing ten weeks after operation, she is in excellent condition, has a normal blood sugar, a satisfactory diet and her tolerance for food is not diminished—her diet and insulin previous to operation proving quite adequate.

Case III.—C. G., age sixty-six, male. Was admitted to the hospital practically in coma with gangrene of the fifth toe of the left foot, due to the paring of a corn. Temperature 100, pulse 110, skin dry, breath strongly acetone. The urine contained 2 per cent. of sugar, 47 grams being excreted in twenty-four hours. On unrestricted diet ketone bodies were found in the urine in abundance. Blood sugar fasting was 200 mgms. per 100 c.c. Patient had never had treatment for diabetes.

He was kept under observation for a week, given forty units of insulin per day with a diet consisting of 90 grams carbohydrate, 70 grams protein, 110 grams fat, at the end of which time an amputation of left leg at the point of election was performed under gas and oxygen anæsthesia. The blood sugar did not rise perceptibly following this and the sugar in the urine was slight. He made a good recovery and the wound healed per primum.

Case IV.—J. B., age forty-six, male. Patient was receiving a diet of carbohydrate 90 grams, protein 85 grams, fat 150 grams and required twenty-five units of insulin daily, in two doses. Insulin was decreased until he used only 17 units daily.

After ten months excellent health with diet and insulin during which he gained two pounds, he contracted a severe influenza. His insulin need increased and his tolerance for fat became much depreciated. He complained of pain, dull in character in the right upper quadrant of the abdomen, and a rounded mass was felt which was diagnosed as an enlarged gall-bladder. An X-ray of the gall-bladder after intravenous iodekon gave no shadow.

The gall-bladder was removed under paravertebral and gas oxygen anæsthesia. Cultures of the content were negative, but the wall of the gall-bladder was infiltrated with leucocytes.

Recovery was uneventful except for the large amount of insulin used—as much as 250 units per day being administered for several days.

Immediately prior to operation he required 160 units daily with a diet of carbohydrate 90 grams, protein 50 grams, fat 100 grams. He was discharged from hospital, using 160 units daily with the same diet as when admitted.

Three months after operation his insulin need was 120 units daily and his diet has been increased to carbohydrate 90 grams, protein 65 grams, and fat 130 grams.

That the story of diabetes is complete is doubted by all. The recent news concerning a new discovery on this Continent with a report from Europe that further discoveries have been made—lead us to believe that in the near future there will be more startling and helpful solutions to this problem. We are by no means satisfied that diabetes mellitus is a disease of the pancreas. There is increasing evidence that other organs and tissues play a

very important part. Also, we are led to believe from reports of able investigators that certain vegetable products, enzymes or other substances may play a very active part in carbohydrate metabolism. We shall look to the future with great expectancy and trust that within our allotted span we may hear the full story told.

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RESULTS OF THE SURGICAL TREATMENT OF CARCINOMA OF THE STOMACH*

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from the surgical clinic of the presbyterian hospital of new york

One is impressed with the frequency with which brilliant results in isolated cases of carcinoma of the stomach are reported by individual surgeons. One is even more impressed by the infrequency of reports from surgical clinics, showing complete follow-up results in all their cases of carcinoma of the stomach.

A study of all cases surgically treated in any one clinic, if it be based on personal observation in a follow-up organization, will obviously offer accurate data on the results of our methods as exemplified by that individual clinic. A collection of such reports from many surgical units would be of great value.

If effort is to be constructive, in the presence of our limited knowledge of the subject as a whole, it must come from a full realization of the facts, with regard to success and failure of treatment, and what factors enter into each.

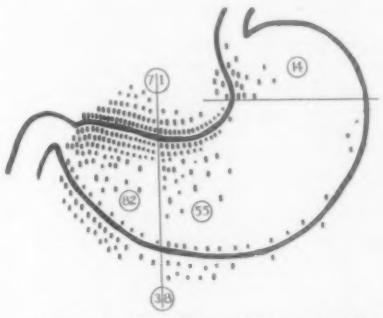


Chart I.—Carcinoma of Stomach.—Site of lesion and metastases as recorded by operator.—Metastases.—Regional lymph-nodes of greater or lesser omenta, 109; Liver, 22; Pancreas, 13; Retroperitoneal nodes, 13; Peritoneum, 3; Small intestine, 2; Colon, 1; Umbilicus, 1; Site not specified, 7; "Practically the entire organ", 3; "Stomach normal", 1. (Autopsy showed high cardiac site.)

Stout, in an analysis of 565 cases of carcinoma of the alimentary tube admitted to the Presbyterian Hospital of New York during a ten-year period, reports 230 carcinomata of the stomach, or 40 per cent.

The purpose of this paper is to present some data on 147 of these cases, surgically treated between 1916 and 1926, with their follow-up results.

There are real difficulties in presenting clearly the results of such a study in a given recent group of cases. The difference in the total number of cases followed for various periods of time is a question with which it is difficult to deal, and one encounters further complications in discussing the cases still being followed for varying lengths of time, referred to as "current cases," some of which have been followed for but a short while. For these reasons, statistics may be confusing and even misleading.

Obviously, an analysis of a group of cases, operated upon thirty years ago, for example, would be more complete and simpler of presentation because of the fact that it would establish a possible long follow-up period for each case, and furthermore, in all probability there would be no current cases, the follow-up records on all having been completed. Unfortunately, the date for this type of study is not available.

* Read before the New York Surgical Society, November 24, 1926.

The following chart does not refer to the particular cases analyzed in this article.

CHART 2

Report of Pathological Findings in Fifty-seven Autopsies of Carcinoma of the Stomach
By Dr. W. C. Von Glahn
Pathological Department, Presbyterian Hospital

Number of cases, 57.

		Cases	Per cent.
Site:			
	Region of pylorus	26	45.6
	Lesser curvature	16	29.8
	Greater curvature	9	17.5
	Walls	14	24.0
Type:			
	Adenocarcinoma	37	64.9
	Scirrhous carcinoma	13	22.8
	Colloid carcinoma	7	12.3
Metastases:			
	Regional lymph-nodes	23	39.6
	Retroperitoneal lymph-nodes	19	32.7
	Mesenteric lymph-nodes	9	15.5
	Mediastinal lymph-nodes	8	13.8
	Bronchial lymph-nodes	1	1.7
	Liver	23	39.6
	Peritoneum	11	18.9
	Lung	10	17.2
	Pancreas	9	15.5
	Omentum	9	15.5
	Pleura	7	12.0
	Intestine	3	5.2
	Colon	2	3.5
	Diaphragm	3	5.2
	Adrenal	4	7.0
	Heart	1	1.7
	Mesentery	4	7.0
	Ovary	4	7.0
	Breast	1	1.7
	Uterus	1	1.7
	Kidney	4	7.0
	Ureters	1	1.7
	Tubes	1	1.7
	Umbilicus	1	1.7
	Bones	2	3.5
	Spleen	1	1.7
	Thyroid	1	1.7

THE FOLLOWING STATISTICS REFER TO CASES ANALYZED BY THE AUTHOR

No. of cases: 147 (males, 97; females, 50; or approximately 50 per cent).
Age: Youngest, 33 years (9 cases under thirty-five years).

20–30 years	0
30–40 years	20
40–50 years	35
50–60 years	57
60–70 years	30
70–80 years	5

Nationality.—Nineteen nationalities are represented in this group, a fact which has no significance other than that it is representative of the international character of the clinical material in a given New York Hospital at a given site.

Occupation.—This factor seemed to be irrelevant in this series.

Outstanding Symptoms.—Duration before admission of symptoms directly referable to the gastro-intestinal tract was as follows: Shortest duration, one week; longest duration, three years. The average length of time during which a patient had noticed symptoms which, upon careful investigation, seemed to refer directly to gastro-intestinal tract, was eight months. Records of seven cases discarded as incomplete in this detail.

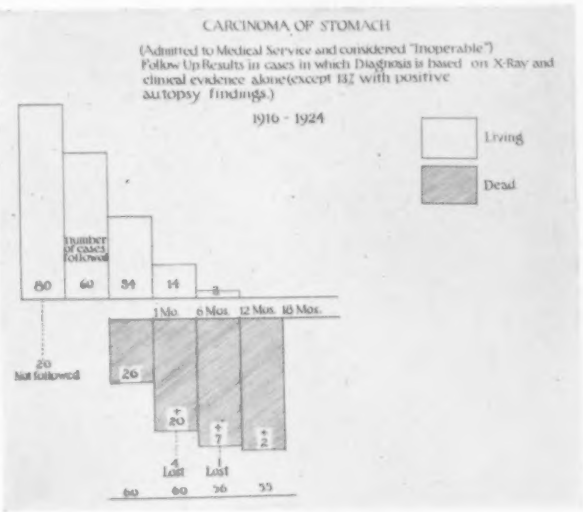


CHART 3.

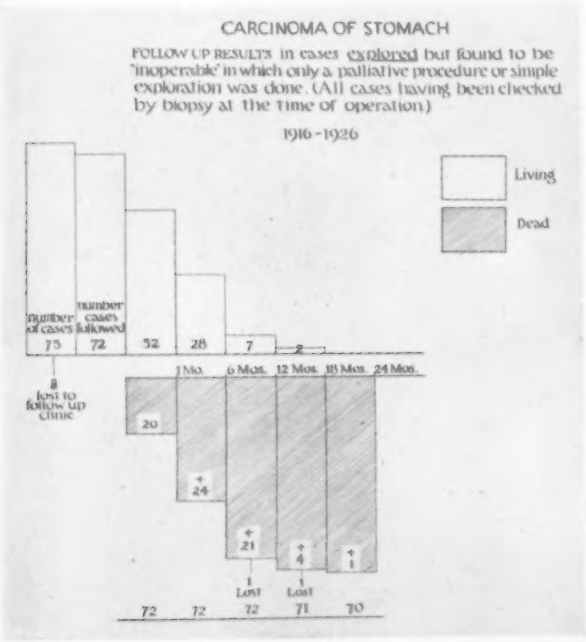
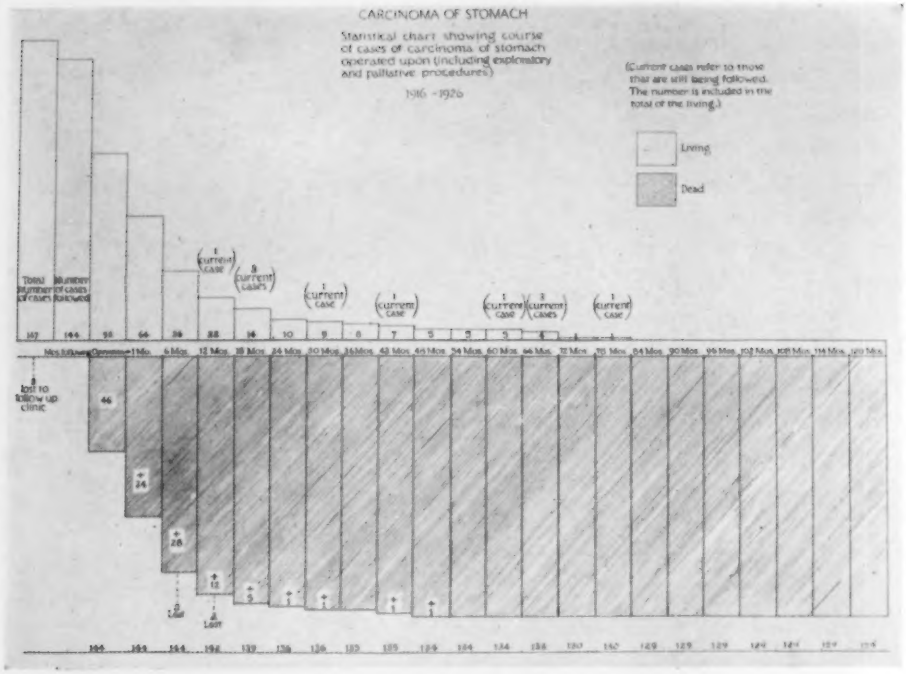


CHART 4.

Loss of Weight.—In only two cases in this series, where it was recorded, was there found to be no loss of weight up to the time of admission. In 125 cases, the average loss of weight was thirty pounds. In 22 cases, weight loss was inaccurately expressed, as for example, "considerable" or "marked," and therefore in those instances the records were useless. An accurate estimation of exact period of time in which weight loss had occurred could not be made from available data, but in many cases it preceded onset of gastro-intestinal symptoms, and had at first been disregarded by patient.


CARCINOMA OF STOMACH
Statistical chart showing course of cases of carcinoma of stomach operated upon (including exploratory and palliative procedures)
1916 - 1926
(Current cases refer to those that are still being followed. The number is included in the total of the living.)
Living
Dead
Total number of cases
Number of cases followed
167
144
98
66
39
28
16
10
9
8
7
5
5
5
4
1
1
1 current case
3 current cases
1 current case
1 current case
1 current case
3 current cases
1 current case
Lost to follow up clinic
46
24
28
2 Lost
4 Lost
1
1
1

Pain.—In 122 cases—or 86 per cent.—pain was a distinct symptom. In this analysis, discomfort, a feeling of fulness, etc., were not included under the heading of "pain." In 20 cases, or 14 per cent., there was absence of pain before admission. In five cases, accurate data was available.

Vomiting.—In 103—or 71 per cent.—of the cases, repeated vomiting was recorded. In 42—or 29 per cent.—the history recorded the absence of vomiting. In two cases this feature was not noted.

FIG. 1.—Case I.

Abdominal Mass.—In 78 cases—more than half—an abdominal mass had been recorded by the staff before operation. In 62 cases—or 44 per cent.—the absence of an abdominal mass had been recorded. In seven cases, no note had been made concerning a mass.

The features of the above statistics, which especially warrant reflection, would seem to be as follows:

FIG. 2.—Case I.

Nine of the cases which, upon exploration, were found to present extensive carcinoma of the stomach, were patients under thirty-five years of age.

The average duration of symptoms directly referable to the gastro-intestinal tract was—in this group—eight months. It is obvious that in many of these cases careful investigation by the patient's physician would have made possible a more hopeful outcome by earlier operation.

The subtle factor of unexplained loss of weight or strength in the cancer-bearing age is one which must constantly be borne in mind by every prac-

titioner, for it is not infrequently the only early danger signal in cancer of the stomach, as in cancer elsewhere.

The writer was impressed by the high percentage of cases in which actual pain was a real feature, viz.: 86 per cent. This is without question especially high in this series. On the other hand, when one considers the fact that 71 per cent. of the cases complained of repeated vomiting, it gives one an idea of the relatively advanced type of lesion in this particular group. This fact is further emphasized by the evidence of an abdominal mass, which was present in more than half of the total number of cases, as noted before operation.

FIG. 3.—Case I.

Chart 1 represents the anatomical site, as recorded by the operator, with lymph-node or other metastatic sites noted.

Following this is a more accurate statistical chart, made by Dr. Von Glahn, as a result of complete autopsy study, in which the limitations for complete exploration, encountered by the surgeon, are eliminated. (See Chart 2.)

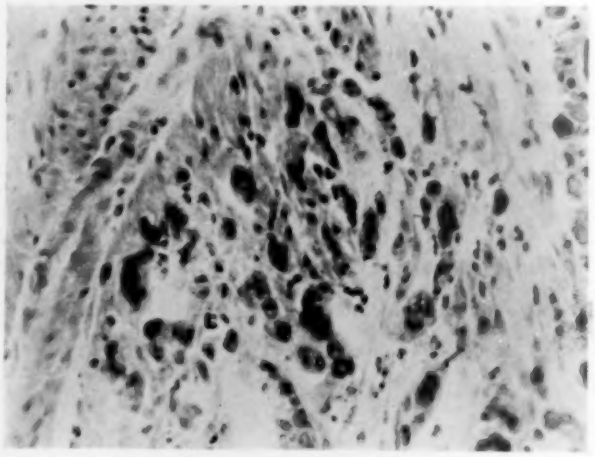


FIG. 4.—Case I.

The follow-up results are recorded by the foregoing charts, in which is shown the outcome in every case of carcinoma of the stomach (with the exception of three cases lost to follow-up) operated upon in the Presbyterian Hospital during the given period, whether or not reaction was possible. Every case is included, despite the fact that in a certain group there was no possibility of radical removal of the growth.

The course of untreated—but proven—carcinoma of the stomach, as when a simple exploration with biopsy is done, must engage our attention as well as the case in which radical resection is possible. The results of resection must

be compared not only with normal individuals, but with results carefully noted in untreated cases, in order to arrive at a true evaluation of therapy in this disease. This seems particularly important in view of the statistics, recently published, emphasizing the duration of life in cases of untreated cancer in various anatomical sites.

CONCLUSIONS

One cannot, of course, draw definite conclusions from the study of such a small series. On the other hand, one gains definite impressions from even a small number of cases, if carefully followed.

FIG. 5.—Case III.

1. In the above study, the cases were well-advanced upon admission to the hospital, due to the failure on the part of the examining physician, in the great majority of cases, to recognize the possibility of cancer. This fact stands out, not only because of the advanced pathology found, but because of the average duration of symptoms, which was eight months. In only 32 cases out of a total of 147, did the operator feel that an attempt to resect was justified.

2. X-ray examination of the stomach should be carried out wherever even a suspicion of carcinoma of the stomach arises, and in fact even when only unexplained loss of weight exists. X-ray facilities should be afforded the poor patient at a nominal cost.

3. Exploration is not contra-indicated by an abdominal mass, and resection should be attempted, when metastases are not present, in cases presenting large local lesions, whenever such radical procedure is technically possible.

4. Enlarged nodes in the regional lymph-glands are not infrequently hyperplastic.

5. The removal of a very extensive local growth may be followed by a

brilliant result. Relative prognosis is difficult, despite gross and microscopic study of the specimen.

6. Many patients are relieved of distressing symptoms by a palliative procedure when a radical operation is impossible.

7. In this series, the mortality following radical operation is higher than the condition of the patients or the technical difficulties justify. Concentration of the work, in the general hospital, to a small group of men particularly interested and especially trained by experience in this branch of surgery, will reduce the operative mortality. The fact that, of 32 cases in this series of cases of carcinoma of the stomach, where resection was carried out, five patients are alive and well after a period of five years, is gratifying.

FIG. 6.—Case III.

8. A 15 per cent. satisfactory result for the five-year period in this group of relatively advanced carcinoma of the stomach, should be a source of renewed vigor in attacking the problem. Concentration should be directed to early diagnosis, lowering operative mortality by increased effort in ante-operative, operative, and post-operative skill in handling these cases, and finally by constant, undivided attention, in maintaining a Follow-up Clinic which has for its aim 100 per cent. data, consistently recorded by personal interview and examination. Maintenance of this concentrated effort is already under way in this clinic.

CASES

(No. I.) J. S. (A patient of Doctor Parsons'.) Female, fifty-five years of age. No. 54,148. Fifty-four months after operation.

The patient came to the hospital on May 22, 1922, complaining of "indigestion," distress in upper abdomen, sour eructations, and loss of weight (thirty pounds in one year). At examination, no mass could be made out in the abdomen.

X-ray showed a filling defect of the antrum, on the lesser curvature side, involving the pylorus. There was considerable residue.

At operation, Doctor Parsons found upon the lesser curvature in the prepyloric region, "an indurated mass 3 cm. in diameter, involving the stomach to within 1 cm. of the pylorus, obstructing this by its size. The centre of the mass presented a deep crater. There were a few enlarged lymph-nodes in the lesser omentum. Just below the greater curvature, another enlarged node was found, which was soft. The liver and pancreas appeared normal. A resection was performed with an anterior end-to-side anastomosis (Polya-Balfour) with entero-enterostomy."

The pathological report showed "adenocarcinoma of the stomach. Sections of all accompanying lymph-nodes give no evidence of metastases."

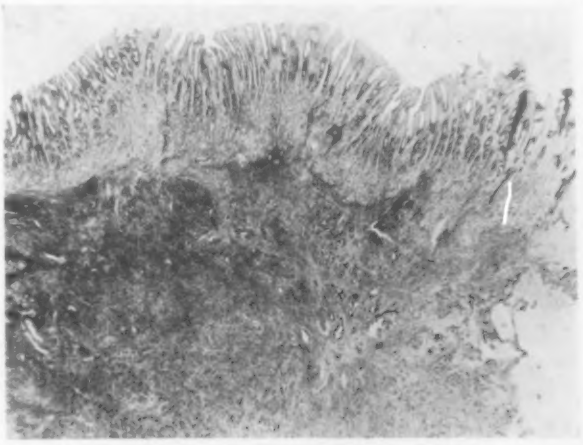


FIG. 7.—Case III.

The post-operative course was uneventful.

X-ray follow-up at one year and at two years after operation revealed a normally functioning gastro-jejunostomy.

It is now fifty-four months (four and a half years) after operation, and the patient is without symptoms, economically capable, and physical examination reveals a firm, abdominal scar, with no evidence of further trouble. The patient weighs thirty-three pounds more than when admitted to the hospital.

(No. II.) M. G. (A patient of Dr. Adrian Lambert's.) Female, thirty-four years of age. No. 50,098. Sixty-six months after operation.

The patient was admitted to the hospital, May 4, 1921, with a two months' history of "pain and a lump" in the abdomen, vomiting and considerable loss of weight.

Physical examination revealed "a firm, large mass to the left of the umbilicus." X-ray showed "a large filling defect on the greater curvature side of the stomach, near—but not involving—the pylorus."

Doctor Lambert operated upon the patient in May, 1921 (five and a half years ago), finding "on the greater curvature, about 5 cm. from the pylorus, a large mass, 6 cm. in diameter, projecting into the stomach. The lesion was more extensive posteriorly than anteriorly. The mass was firmly adherent to the transverse meso-colon directly along the path of the medio-colic artery; in fact, the colica media was incorporated so intimately in the mass that it could not be dissected out with any degree of success. The liver and pancreas were apparently not involved. A partial gastrectomy was done, leaving about 10 cm. of the stomach. The duodenal and gastric stumps were closed, and a posterior gastro-jejunostomy was performed by suture, after which the compromised portion of the transverse colon was resected, and an end-to-end colostomy carried out."

The pathological report was as follows: "Springing from the posterior wall of the stomach and involving the lesser curvature, is a large, nodular, fungating tumor, 8 cm. long and involving the entire circumference of the stomach, with the exception of about 4 cm. of the mucous membrane on the anterior surface. Along the greater curvature there are many enlarged lymph-nodes, varying from one to one and one-half cm. in

diameter, which give no gross evidence of being involved. One smaller node is found along the lesser curvature. A segment of colon 8 cm. long shows no gross involvement."

Microscopic examination showed the tumor to be made up of closely packed alveolar strands of deeply staining epitheliar cells, many of which showed mitosis. Sections from the lymph-nodes and portion of colon showed no involvement.

Diagnosis: "Carcinoma of the stomach."

It is now five and one-half years since operation, and the patient is free of symptoms, except for the occasional belching of gas. She weighs thirteen pounds more than six years ago. She is a widow with seven children, of whom the oldest is fifteen and the youngest seven years. Her activities and responsibilities are proportionate.

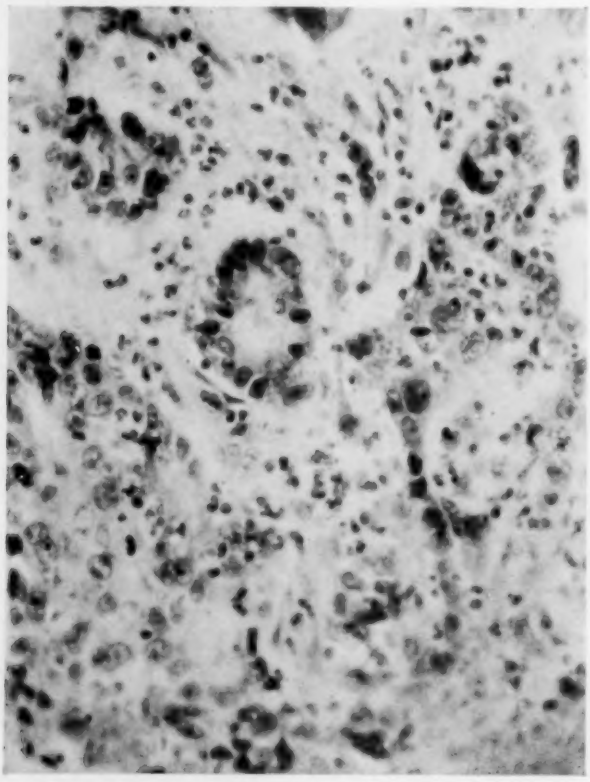


FIG. 8.—Case III.

Physical examination shows that there is slight diastasis of the recti, with no bulge. An X-ray about five years after operation showed a normally functioning gastro-jejunostomy. An X-ray of the spine five and one-half years after operation showed no evidence of metastasis.

(No. III.) J. S. (A patient of Doctor Whipple's.) Male, aged fifty-nine years. No. 49,427. Sixty-eight months after operation.

The patient was admitted to the hospital, March 14, 1921, complaining of cramps in the abdomen for about one year, coming on one hour after eating, and disappearing spontaneously. He had lost about five pounds in the one year. No abdominal mass was noted upon examination.

X-ray revealed a filling defect in the middle third of the greater curvature. There was no retention.

At operation, Doctor Whipple found "a dense, hard, infiltrating mass, involving both anterior and posterior walls of the stomach. It was freely movable and gave the impression of lending itself readily to excision. But after the vessels along the greater and lesser curvatures had been ligated, and the pylorus resected, it was found that the posterior wall at its lower border was adherent to the mesocolon to the left of the colica-media vessels, so that it was necessary to excise a portion of the mesocolon. Fortunately this involved no large vessel. The liver appeared negative. Hard nodes were found along the lesser curvature. A resection with Moynihan technic was carried out."

Pathological report was "adenocarcinoma of the stomach." Sections of lymph-nodes were negative.

The post-operative course was uneventful. Doctor Whipple's final note was to the effect that in this case the "prognosis was poor."

X-ray two years after operation gave no evidence of anything suggesting recurrence, and X-ray of the chest, four years after operation, was negative.

It is now five years and eight months since operation, and the patient is symptom-free, working as a porter in a ferry-house. Appetite is excellent, bowels regular. He presents a post-operative hernia which permits a more accurate examination of the gastric area. There seems to be no evidence whatever of recurrence.

FIG. 9.—Case IV.

(No. IV.) F. H. (A patient of Doctor Lambert's.) Male, fifty-five years of age. No. 31,857. Seventy-one months after operation.

This patient was admitted to the hospital in December, 1920, complaining of "pain in the stomach" immediately after eating, during the previous four months. He had lost twenty-five pounds during this period. No abdominal mass was noted.

X-ray showed a six-hour gastric retention, with deformity of the lesser curvature in the pre-pyloric region.

At operation, Doctor Lambert found a mass measuring 5 x 3 cm., oval in shape, involving the pylorus. It was not very hard, and the peritoneal surface showed no special scarring or thickening. The mass was freely movable, and no enlarged lymph-nodes could be felt in the omentum. A partial gastrectomy, with a Polya-Balfour end-to-side anastomosis was done, with an entero-enterostomy.

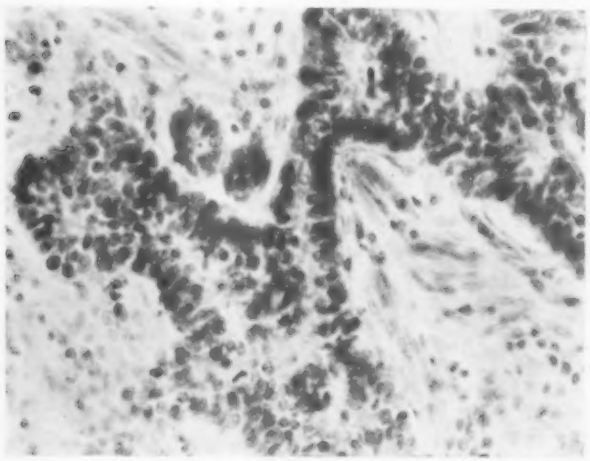


FIG. 10.—Case IV.

Pathological report was "adenocarcinoma, ulcerating"

The post-operative course was uneventful, except for pain after eating, fluoroscopic examination revealing some obstruction to the emptying of the stomach.

A gastro-intestinal X-ray, five and one-half years after the operation, shows a normally functioning gastro-jejunostomy, with no evidence of recurrence. At present—six years after operation, lacking nine days—the patient is without symptoms, except that he has found a large amount of food is best not eaten at one time. The abdominal scar is firm and there is no evidence of recurrence. He has gained weight.

(No. V.) G. A. (A patient of Doctor Lambert's.) Male, fifty years of age. No. 42,856. Eighty-seven months after operation.

The patient was admitted to the hospital in August, 1919, complaining of "hunger pains," "gas on the stomach," and "eructations." There had been a loss of weight of ten pounds in three months.

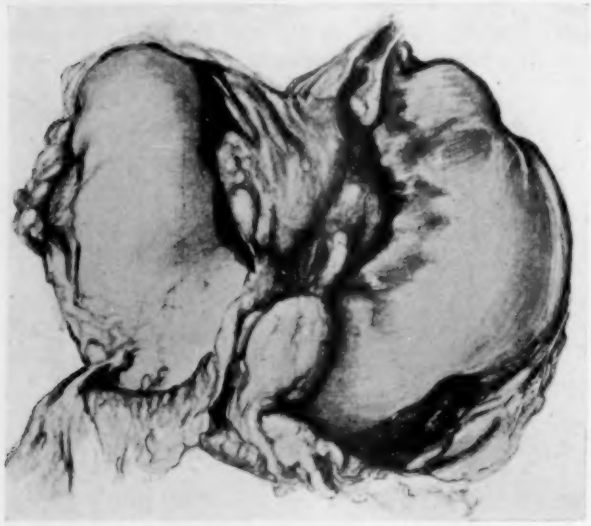


FIG. 11.—Case V.

X-ray showed a large filling defect of the lesser curvature, extending from the mid-portion of the pars media to the pylorus. There was a large gastric retention.

A hard, firm mass, measuring about 4 cm. in diameter, was palpable in the abdomen to the left of the umbilicus. It was freely movable.

At operation, Doctor Lambert found "a large, horseshoe-shaped tumor on the lesser curvature of the stomach, about 2 cm. from the pylorus. The mass was perhaps 5 cm. in diameter. There were some hard, shotty glands in the gastro-hepatic omentum, and there were other glands in the great omentum, near the head of the pancreas. These were free and not matted together. There were no adhesions of the stomach to any other organ, and the liver and pancreas did not appear to be involved. A resection of the Billroth No. 2 type was performed.

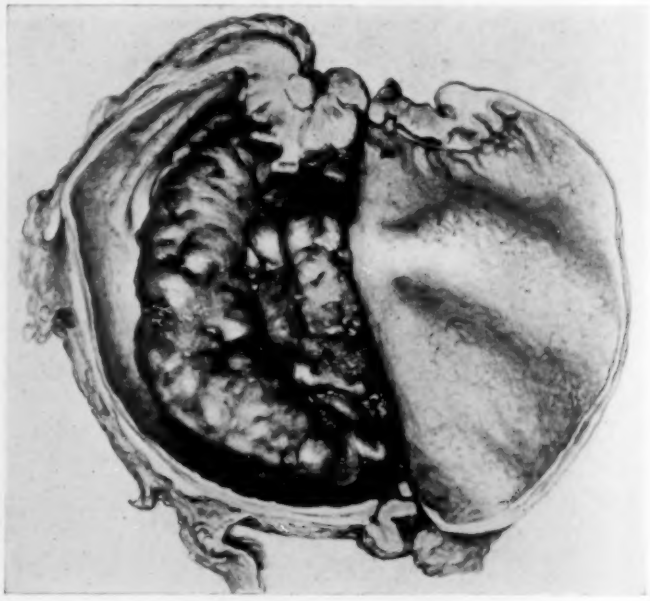


FIG. 12.—Case V.

Pathological report was as follows: "Upon opening the stomach by a longitudinal incision, adjacent to the greater curvature, there is revealed a large, cauliflower-like growth measuring 5 cm. x 8 cm. The tissue of which it is composed tends to be friable, and its surface appears ulcerated. The greater omentum contains several enlarged lymph-nodes, which are hard and white." Microscopic report shows "a very extensive and irregular proliferation of atypical glands throughout the entire section. The cells are large, deeply chromatic, and show many mitoses." Diagnosis: "Adenocarcinoma of the stomach."

The post-operative course was uneventful.

A gastro-intestinal X-ray, four and one-half years after operation, showed no gastric residue and a normally functioning gastro-jejunostomy.

To-day, seven years and three months after operation, the patient's weight remains unchanged and he is symptom-free. He works from eight to five daily at his usual occupation. Physical examination reveals a well-healed scar, with no evidence of further trouble.

The author is indebted to Dr. A. P. Stout of the Surgical Pathological Service for the use of the photographs of gross and microscopic study of the

FIG. 13.—Case V.

specimens in connection with the cases shown. He is also indebted to Dr. W. C. Von Glahn of the Pathological Service for the opportunity of including the autopsy analysis incorporated in the article.

BENIGN STRICTURE OF THE BILE DUCTS*

By Robert T. Miller, Jr., M.D.
of Baltimore, Md.

As surgical experience grows and the information gained during the management of large groups of cases is made available, it becomes increasingly evident that benign stricture of the extra-hepatic bile ducts is rather more than a surgical curiosity. It is a lesion of unsuspected frequency of occurrence, although, as study of the literature suggests, perhaps encountered most frequently as an unexpected finding at operation. There is now at hand, however, a considerable fund of information concerning the various forms of benign stricture as well as records of experiences in the management of a surprisingly large number of cases, so that it is no longer necessary for the surgeon to rely solely upon a hasty decision made under pressure in an effort to solve a problem altogether new. Among the reports and discussions to be found in the literature, those of Eliot, Judd, Mathieu, Delbet and Lafourcade are worthy of note.

Strictures which are the direct consequence of operative trauma are reasonably well understood so far as concerns their cause, prevention and diagnosis. However, these three phases of the other benign strictures are rather obscure, the opinions found in the literature being largely expressions of conjecture rather than of demonstrated fact, and so far as surgical management is concerned, any variety of the condition may well tax the operator's ingenuity to the utmost. Many of those of widest experience feel that the operative problem offered by these cases is among the most difficult in surgery. In view, then, of the increasingly frequent recognition of this lesion, the possibility that its incidence may be increasing as well, and the paucity of knowledge concerning it, personal experience with the disease should be put on record.

During the winter of 1925–1926, through the courtesy of Dr. Charles R. Austrian, there came under my observation the following instance of benign stricture, an isolated case of sufficient interest to warrant report.

The patient is a physician, aged forty years. His past history includes the usual infectious diseases of childhood, a possible though doubtful attack of typhoid fever of four weeks' duration occurring fourteen years before his present illness, and, while serving in the army, an attack of influenza which was followed by a bothersome productive cough, lasting four or five weeks. He has had recurrent infections of one antrum of Highmore. His habits have been particularly good, there being no question of venereal disease or of the use of either tobacco or alcohol. His present illness started five months ago with a sudden attack of exceedingly severe abdominal colic. The pain, which lasted two hours, was localized in an area about three inches in diameter just to the left of the xyphoid cartilage. The following day his upper abdomen was tender

* Read before the American Surgical Association, May 13, 1927.

and the colic was followed by a persistent dull ache. There was considerable general malaise for a day, but active catharsis brought about prompt recovery and he was himself again in two or three days. During the next three months there were five recurrences of a similar nature, the first two of extreme severity and the final three rather milder. The third attack, the most severe of all, was accompanied by pain in the back, vomiting and severe, persistent, general malaise. None of the attacks bore apparent relation to meals or to the kind of food taken. They occurred invariably about the middle of the night and were preceded for about one hour by a feeling of vague abdominal discomfort. For the two months preceding his admission to the hospital, though there was no severe pain, he nevertheless suffered recurring milder attacks of the same general character, increasing flatulence with regurgitation of sour material several hours after meals, and toward the end of this period was nauseated and generally miserable almost constantly. Definite jaundice made its appearance only during the final three weeks before admission; during this time his stools alternated between an acholic and a well-colored state, though without attacks of pain in any way suggesting a stone in the common duct. Although repeatedly observed, the blood never showed a leucocytosis though the proportion of eosinophiles was increased, varying between 15 and 30 per cent. Fifteen pounds in weight were lost in the last three months.

On examination there is found a well-nourished man who shows a distinct though not deep jaundice, both the sclera and the skin over the entire body being distinctly yellowish. The chest is negative. The abdomen is symmetrical and moderately full, with respiratory motions unrestricted and equal upon the two sides. The liver is felt about 8 cm. below the right costal margin, its edge being quite soft, sharp and not tender. There is no tenderness or muscle spasm in the right upper quadrant or elsewhere in the abdomen. The spleen and the kidneys are not palpable. In the right lower quadrant is the scar of an uneventful appendectomy made a number of years ago.

Blood count: Hæmoglobin, 93 per cent.; red blood corpuscles, 4,816,000; white blood corpuscles, 8350.

Coagulation time, 8 minutes; bleeding time, 5 seconds.

Wassermann reaction negative.

Gastric analysis: Free acid 55, combined 17, total 72; lactic acid negative; guaiac test negative; no Oppler-Boas bacilli or sarcinæ.

Bismuth meal: Gastro-intestinal tract is negative except for the possible presence of a few adhesions in the right lower quadrant.

Röntgenogram of the gall-bladder is negative for gall-stones.

Urine examination: Amber; specific gravity, 1014; acid reaction. Bile + +. Otherwise negative.

The phthalein test for renal function shows the excretion of 40 per cent. in two hours.

Blood chemistry: Blood non-protein nitrogen, 33 hgn. per 100 c.c.; blood sugar, 0.130 per cent.

Examination of the stool: Contains a little bile though in the main is quite clay-like in appearance; there is much undigested food and fat, a little mucus and no parasites. The Schmidt test for bilirubin and biliverdin is negative. Guaiac test for blood negative.

Diastase test: Dilution from 0.1 c.c. of fæces to 1.5 c.c. shows a progressively increasing amount of digestion; dilution from 1.5 c.c. to 4 c.c. shows complete digestion.

We have, then, a patient, aged forty, who for five months has had recurring attacks of upper abdominal colic, sometimes of great severity. The attacks, usually preceded by an hour's discomfort, are associated with nausea, occasionally with vomiting, and followed by malaise which lasts two to three days. The latter part of the illness has been marked by increasing digestive trouble, loss of weight and finally by the appearance of jaundice. While under observation the temperature varied between 97.6° and 99.2°, the leucocyte count was not increased and laboratory tests were largely negative. There was a moderate degree of jaundice with bile in the urine. The only abdominal sign was

a palpable liver edge 8 cm. below the costal margin. Definite abdominal tenderness was not found during the seven days of observation. The condition was thought to be common duct obstruction due either to gall-stones or neoplasm. Among the several men who saw this patient, none expressed a more definite opinion. In order to present only the objective evidence obtained during laparotomy, the note made immediately after operation is quoted verbatim:

Right rectus incision. Gall-bladder slightly enlarged, walls markedly thickened; a few adhesions, which were divided. No stones palpated in the gall-bladder. On palpation of the common duct, it suggested a superficial saphenous vein occluded by organized clots. The whole duct was distinctly felt as a hard, clearly defined affair, of a little less than normal size, and it apparently contained a succession of hard objects which were assumed to be stones. The duct was opened; its wall was found to be greatly thickened throughout, its lumen much diminished in size, and lying in it were a few flakes of deeply colored, soft debris, apparently inspissated mucus. No bile came from the duct until a probe had been somewhat forcibly inserted into the hepatic duct, whereupon a small amount of very faintly colored secretion appeared. It was impossible to pass anything larger than a very fine probe into the duodenum, the lumen of the duct being all but occluded by its thickened wall. The exact nature of the change in the wall of the duct was not understood, but because of bothersome bleeding no specimen was excised for diagnosis. The duct was fairly accurately closed with interrupted silk, and cholecyst-gastrostomy was made by a running continuous black silk stitch posteriorly with anteriorly two layers, the first mattress and the second of continuous black silk. The wound was then closed in layers with two cigarette drains reaching to the common duct.

Operation lasted something over two hours; the patient left the table in good condition.

The first two post-operative days passed without notable incident but were followed by an abrupt change in the patient's condition, which became exceedingly critical. He vomited copious amounts of bloody material and passed blood per rectum. He was transfused in all seven times, receiving over 3000 c.c. of citrated blood. After the seventh transfusion the bleeding, which was assumed to be due to jaundice, stopped, and from this time his improvement was steady and reasonably rapid. On the twelfth day after operation examination of the stool showed the presence of bile, tests up to that time being uncertain because of the blood in the gastro-intestinal tract. Sixteen days after operation the wound was completely healed and jaundice was rapidly subsiding. When discharged at the end of five weeks there was no evidence of jaundice externally, though the urine still showed a slight trace of bile. He still complained slightly of mild abdominal discomfort which was relieved by soda. Convalescence was purposely prolonged, but in three months he had largely regained his weight and strength and was apparently in good health. A year after operation the patient had a severe attack of influenza which was followed by a return of the original symptoms of upper abdominal colic, indigestion and mild jaundice at irregular intervals, and he was again losing weight. His condition, however, was in no way comparable in severity to that of the previous year, and it was thought an explanation might be found in the state of relative exhaustion into which he had again allowed hard work to put him.

The case is an instance of stenosis of the common duct in its entire length. The cause of the condition is quite obscure. To refer to spontaneous occurrence explains nothing. Trauma is not a factor inasmuch as the biliary ducts had never been previously exposed. At operation there was no evidence of gall-stones or "sand."

Adhesions about the gall-bladder and thickening of its wall, both of which were found in this case, are certain evidences of inflammation. Inflammation

of the gall-bladder frequently leads to the formation of gall-stones, but this is neither a constant nor an inevitable result. The relation between cholecystitis and calculus is in a way analogous to that between typhoid fever and intestinal perforation: the one is a frequent but not a certain sequence of the other. It is entirely possible—it seems indeed altogether probable—that this patient's biliary tract had never contained a gall-stone. For the purpose of argument, however, let us assume the former presence of gall-stones; it is difficult to understand how the irritation or trauma of a calculus could be so generally and equally distributed as to result in such an extreme fibrosis distributed uniformly throughout the entire length of the common duct. Furthermore, stones of sufficient size and irregularity to cause so marked an alteration in its wall would have no chance of escape from such a duct as was disclosed at operation, or even from a normal duct; and yet neither in my case nor in two similar cases cited later in this paper were stones found. Finally there is the fact that the duct stricture associated with and obviously due to a stone is typically a linear or quite narrow circumferential scar, a quite different thing from general fibrosis. In view of these facts it would not appear sound reasoning to assume the presence of stones and their causal relation to the demonstrated lesion simply because of upper abdominal pain, particularly since the attacks of pain were by no means typical of common duct colic. There is therefore reasonably good evidence that this lesion, diffuse stenosis of the common duct due to extreme fibrosis uniformly distributed throughout its wall, characterizes a distinct group of benign strictures which is quite apart from either the group due to trauma or that due to stone.

There are two general groups of benign strictures of the extra-hepatic biliary ducts, viz., congenital and acquired. Permanent jaundice appearing soon after birth is all but pathognomonic of the first-mentioned group, though very occasionally, as in the case of Treves and certain others, it may not appear before practically adult life. There is a wide variety of anomalies, well described in several excellent papers, notable among them being those of Holmes and Milne; suffice it here to say that the commonest is a localized stricture at the ampulla. Although there is normally at this point in the duct a narrowing which in an infant is extreme, the exact cause of its conversion into a pathological stricture is obscure. The conventional suggestion that it is due to toxic material in the mother's blood seems of doubtful value in view of a report from England made in 1914 by Feldman, who found congenital obliteration of the common duct in one only of a pair of twins. Jaundice appeared at the end of three weeks and the patient died nine weeks later. His brother was perfectly healthy. Were prenatal absorption of toxins from the mother the cause of congenital stricture, it is not clear why but one of a pair of twins should be affected.

Acquired strictures of the extra-hepatic biliary ducts are for the most part not of such obscure origin. Two groups are recognized, the first due to trauma and the second to gall-stones. The injury resulting in stricture of the common duct has usually occurred during removal of the gall-bladder. A

shrunken, fibrosed gall-bladder buried in adhesions and tucked well up under the edge of a liver which cannot be drawn into the wound may well try any surgeon's ability. Not only is exposure difficult, but the finer anatomy is frequently so obscured by inflammatory changes that recognition of the cystic artery is uncertain, if not indeed impossible. It appears that the common duct has been injured most frequently during efforts to control hemorrhage. In a deep field, obscured by blood, attempts to clamp a bleeding cystic artery buried in adhesions are necessarily fraught with hazard; anomalies in the anatomy of the cystic artery and the cystic duct may enhance the difficulty. Such a situation demands accurate work carried out under exact visual control. The duct may be injured unwittingly, the first intimation of misfortune being the failure of jaundice to clear promptly or the persistence of a biliary fistul. As discussion of this matter grows more current, one finds an increasing tendency on the part of those of experience to warn urgently against blind operating. If one identifies the cystic duct, the common duct and the cystic artery, cholecystectomy may be carried out as an exact procedure without danger of injury to the common duct. If inflammatory changes prevent accurate identification of these structures, one may still insure safety in the majority of instances by careful inspection of the tissue to be divided before applying the clamp. This no doubt prolongs the operation a little but an additional few minutes under ether is as nothing when weighed against the lot of one whose common duct has been gravely injured.

In contrast to the traumatic group of strictures stand those due to gall-stones and usually spoken of as inflammatory. These are typically local lesions quite limited in extent, and may occur anywhere along the common duct, most frequently perhaps in its lower portion. The stricture usually involves but a narrow circumferential area, the condition of the rest of the duct being such as to offer some chance of successful repair. It is assumed that they result directly from traumatism of the mucosal surface by gall-stones: an assumption which seems entirely reasonable in view of the frequency with which stones are found at or near the site of stricture. The stricture is really a contracture of the scar tissue caused by the ulcer, itself in turn the result of injury by a calculus. At times there is also a redundant fold of mucosa acting more or less as a valve. Delageniere has described a case in which two stones were caught in the common duct, the lower, impacted near the ampulla, being almost completely covered on its hepatic side by a diaphragm of mucosa with a tiny central opening; after splitting this diaphragm the stone was displaced upward into an accessible part of the duct whence it was removed. Others have described such valve-like folds of mucosa. The so-called inflammatory strictures, then, appear to be characterized by their almost linear character, the limited extent of involvement of the duct which is elsewhere relatively normal, their frequent association with gall-stones and occasionally with valve-like folds of mucosa.

There remains finally for consideration that type of stricture in the production of which trauma plays no part and of which gall-stones presumably

are not the cause, a group illustrated by the case presented in this paper. The essential change is a diffuse, uniformly distributed fibrosis of the wall of the common duct resulting in compression and narrowing of its lumen to the point of all but complete occlusion. A considerable portion of the total length of the duct is involved, perhaps most frequently the entire common duct, and at times the process may extend up into the hepatic duct. It is apparently a more or less uniform change throughout the wall of the entire involved area. Such a duct on palpation resembles a hard, cord-like mass. In the case described above, it suggested a thick-walled vein enclosing a number of organized thrombi. The transverse dimension of the duct was rather smaller than normal, and upon opening it one was immediately impressed with the thickness and toughness of the wall. The edges of the opened duct everted in most striking fashion and it was evident that the lumen had been all but completely obliterated by compression throughout its entire length. There was no point at which the change seemed to be exaggerated above that found elsewhere.

Two cases, almost exact counterparts of my case, have recently been reported by Delbet and Lafourcade. The first, that of Delbet, concerns a man of forty-eight who for two years had recurring attacks of epigastric pain, usually appearing shortly after eating and sometimes associated with vomiting. The pain at times radiated to his back. Jaundice, though not of extreme degree, appeared but twelve days before admission to the hospital. On examination there was found extreme tenderness in the epigastrium, marked spasm of the right rectus muscle, definite jaundice and stools which were largely but not completely decolored. His temperature was 38°, the estimation of amylase normal and the Wassermann reaction negative. Delbet considered the condition a stone in the common duct. At operation there was found, buried in light adhesions, a thin-walled gall-bladder which was slightly distended and contained bile. In the right border of the lesser omentum there was found a dark cord the size of one's "little finger," which was assumed to be the dilated common duct. This was punctured with a hypodermic needle and though no bile entered the syringe, a tiny bit escaped through the wound, making recognition of the duct positive. Delbet incised the cord little by little, traversing many fibrous layers, and finally opened a common duct with extremely thick walls and very small lumen. He was then able without great difficulty to pass a very fine catheter through the lower end of the duct into the duodenum. The catheter could not be passed toward the liver but he nevertheless judged that the duct was not completely occluded since "I found a little bile above." Because of the extensive change in the common duct, the impossibility of forcibly dilating it and the difficulty of repairing the opening which he had made, Delbet concluded the operation by anastomosing the gall-bladder to the duodenum, a logical manœuvre in view of the presence of bile in the gall-bladder. No gall-stones were encountered during the operation. Convalescence was without incident and jaundice rapidly disappeared. The escape of a considerable quantity of bile from the wound demonstrated clearly that the biliary passages above the incision in the common duct were not completely obliterated. Delbet exhibited his patient in good health a month after operation, and remarked, "How does the bile pass into the gut? Is it by the common duct or the cholecystduodenostomy or both? I see no means of knowing."

Lafourcade in 1925 reported two benign strictures of the common duct, with the second only of which we are concerned here. His patient was a man of fifty-eight, who for thirty years had had repeated attacks of "hepatic colic." Jaundice, which had never been extreme, became much more pronounced seven months before admission. When

the patient, greatly weakened by the long illness, applied for treatment, he was deeply jaundiced and had clay-colored stools as well as bile in the urine. The liver edge was felt four finger-breadths below the right costal margin. Lafourcade thought it a case of common duct stone. At operation there was found a gall-bladder much reduced in size and buried in adhesions which were widespread over the inferior surface of the liver. The common duct was extremely indurated throughout its entire length and when opened the wall was seen to be markedly fibrosed and greatly thickened. Exploration was thorough inasmuch as during the course of it the duodenum was mobilized and reflected toward the midline. The author specifies that the wall of the duct was ½ cm. in thickness and its lumen so reduced in size that a stylette could be inserted only with difficulty. The hepatic duct was apparently not greatly changed, for Lafourcade divided it and inserted a rubber tube whose distal end was carried into the duodenum through its posterior wall. In spite of the great decrease of jaundice, death occurred forty-eight hours later. Unfortunately, no autopsy is reported. It is noteworthy that no stones were found in the biliary tract in this case.

These three cases may be regarded as representative of a distinct group of benign strictures characterized by extreme fibrous thickening in the wall of the common duct throughout its entire length, resulting in great diminution of the lumen and obstructive jaundice. Each case showed chronic inflammation of the gall-bladder, but in none were gall-stones found. The change in the wall of the common duct is surely the result of inflammation, but there is no obvious explanation of its strikingly localized character. Objections to the idea that the lesion results from the irritation and traumata of gall-stones were pointed out above. These factors are concerned in the production of limited localized strictures but can scarcely be the cause of so diffuse and uniform an alteration as is described. Both gall-stones and fibrosis are the result of inflammation of the extrahepatic biliary system. The tissue change is usually maximum in the wall of the gall-bladder but under conditions as yet obscure, the wall of the common and hepatic ducts may be altered in quite the same way. At times it seems the pathological alteration may be almost limited to the common and hepatic ducts with little more than a relatively minor change in the gall-bladder; when such a process of fibrosis reaches an extreme degree the inevitable result must be obstructive jaundice.

Eliot remarks that a stricture may develop without the associated operation, and in discussing etiology says: "They may also follow an infectious cholangitis terminating in necrosis of the mucous membrane of the duct, in which event the larger portion of the duct may become stenosed or obliterated." This explanation is hardly applicable to Delbet's case or to mine since so grave a disturbance would undoubtedly be associated with much more severe constitutional symptoms than either case showed. Judd remarks, "Diffuse strictures rarely come to the attention of the surgeon. All extrahepatic ducts may be involved in the cicatricial process. The condition occurs usually as a congenital artesia of the bile ducts and is most often due to obliterative cholangitis." One may add that although the so-called diffuse stricture due to fibrosis of the wall of the common duct is not common, nevertheless sufficient evidence is now at hand to warrant its recognition as well as to indicate that it is a condition quite apart from congenital or traumatic

stricture and probably quite different in mode of production from the strictures caused by gall-stones. There seems good reason to consider it an inflammatory lesion which results in an essential fibrosis of the wall of the common duct. Neither traumatism nor gall-stones appear to be a factor in its causation. It is then in a sense to be regarded as a type of cholangitis.

There seems to be nothing distinctive in the clinical history of such cases. They come to operation as common duct obstructions the cause of which is assumed to be a stone or a neoplasm. In Delbet's case jaundice appeared only during the final twelve days of an illness of two years' duration, and in my case only during the final three weeks of a five months' illness. Eliot has remarked that "the stricture must be far advanced before the resulting stenosis without associated inflammation will be sufficient to cause jaundice." These facts suggest that marked delay in the appearance of jaundice in a long-standing history of recurring attacks of hepatic colic may possibly prove to be a feature of some importance in diagnosis. Until more is known about the disease, however, its recognition will not be possible before the common duct is exposed at operation.

The purpose of this paper not being a discussion of the surgical management of benign strictures of the bile ducts, suffice it to say that the reported experience with diffuse stenosis of the common duct indicates the wisdom of reëstablishing the current of bile to the intestines by means of cholecystgastrostomy or cholecystenterostomy when the state of the gall-bladder and the ducts above permits. There may be added the suggestion that with the common duct occluded, the functional success of such an anastomosis is reasonably well assured even though there remain in the hepatic and cystic ducts nothing more than a meagre lumen. When practicable, it is certainly wise to make this anastomosis, for it offers the hope that drainage so achieved may bring about resolution of the inflammatory tissue and restoration of the lumen of the ducts. Substitution of the ducts by tubes of living tissue or of rubber has not as yet proved of great value.

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FRACTURES OF THE EXTERNAL CONDYLE OF THE HUMERUS WITH ROTATION

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There is in children a characteristic group of fractures of the external condyle with outward rotation of the fragment into an irreducible position. They are infrequent. Their importance rests on the fact of their irreducibility and the consequent indication for treatment, which is preferably in my opinion early open reposition.

Kocher [1] in 1896 reported a successful operation on such a case. Stimson,[2] Cotton,[3] Stone [4] and others have described this type of fracture and its operative treatment. The purpose of this report is to emphasize the fact that these fractures form a characteristic group which should be recognized and appropriately treated. Four personal cases and a fifth, included through the courtesy of Dr. Edward J. Donovan, are presented.

These fractures occur in younger children, the ages varying from five to ten years in this series. The mechanism of production is not explained satisfactorily from any of the histories, several stating that the child fell on his elbow and one that he fell twisting his arm under him.

The fracture line runs from the region of the external epicondyle downward and inward into the joint close to the junction of the capitellum and trochlea, coinciding in part of its extent with the epiphyseal line of the capitellum. The fixed point of attachment is through the external lateral ligament to the radius below. The fractured surface in the typical case is turned outward so that it is subcutaneous, while the articular surface of the capitellum is directed toward the fractured surface of the shaft.

On examination a movable fragment of bone is felt to the outer side of the injured joint. X-ray reveals the displacement but may or may not indicate the rotation of the fragment.

An attempt at closed reduction seems advisable and was made in all the cases here reported. Operation has in each instance demonstrated to the satisfaction of the operator that bloodless reposition was out of the question.

In the experience of the writer, external lateral incision over the fragment gives a satisfactory exposure. Its relations can then be established and it can be turned and pried into place. If a complete reduction of the fragment is accomplished it tends to remain in place and a catgut suture through the periosteum is sufficient fixation together with subsequent immobilization of the joint in a flexed position.

Stimson states that in two of his three operated cases the reduction was accomplished with difficulty. In this series of five cases, the reduction was

incomplete in one of the writers, the fragment remaining anterior. Most of the failures at reduction will probably be in relatively late cases. It is important, therefore, that the condition be recognized promptly so that operation may be carried out at an early date, preferably by the end of the first week. Stone states that reposition may be done up to about six weeks. It would probably become very difficult before this time was passed.

If reposition is found impossible at operation, or if a patient presents himself with disability after it is too late to hope for reposition, the fragment should be excised. Experience shows that this may be done with a good functional result. It is clearly, however, not the method of choice.

Siris [5] has reported a case of this type treated without operation. A perfect functional result was obtained. There was of course a deformity, which, however, Doctor Siris [6] has found becomes less with passage of time. This deformity to my mind outweighs the risk of an open operative procedure under favorable circumstances.

FIG. 1.—Case IV. C. S. Fracture of external condyle with irreducible outward rotation. It seems pretty clear from this X-ray that the fractured surface is outward.

CASE I.—F. S., eight years old, fell from a window to the ground, landing on the left elbow. (1916.) Examination in the out-patient department revealed a freely movable fragment of bone directly under the skin lateral to the external condyle. The X-ray report was fracture of the external condyle, including the articular facet for the radius, with displacement to the outer side and forward. After unsuccessful attempts at reduction he was admitted to the hospital. Operation was done eight days after injury. A lateral incision was made. The fractured surface was found to be rotated outward and downward. The fragment was replaced and secured by interrupted sutures through periosteum and fascia. The arm was put up in flexion. Examination seven years after operation showed a normal appearing elbow with function completely restored save for two or three degrees limitation in both flexion and extension.

CASE II.—G. F., six years old, fell off a cart twisting the right arm under him. (1919.) Operation three days after injury through lateral incision. The outwardly displaced external condylar fragment, which included the capitellum, was turned so that the fractured surface was subcutaneous. Reduction was thought to be accomplished in this case but the post-operative X-ray showed that the fragment was anterior. The patient was discharged on the forty-first day with flexion to 90 degrees and extension to 140 degrees. It has not been possible to reëxamine this boy as he lives out of town. A report from his mother seven years after operation is to the effect that he uses the injured arm as well as the other. Flexion is not complete, extension is nearly so. There is no information as to deformity.

Case III.—J. S., ten years old, fell, striking the back of his left elbow. (1920.) A bony fragment could be felt displaced forward and laterally from the external condyle. X-ray showed an external condylar fracture involving the capitellum with the fragment completely dislocated away from the humerus. Closed reduction was unsuccessful. Operation through a lateral incision six days after injury. The fragment was rotated outward. It was reduced, secured with periosteal sutures and the arm put up in flexion. Four months after operation it was noted that there was slight limitation of extension remaining. One year later the functional result was perfect.

Case IV.—C. S., five years old, fell from a cart, striking his right arm. (1923.) On examination a loose bony fragment was felt to the outer side of the external condylar

Fig. 2.—Same as Fig. 1, after three years. There is a little alteration of the outline of the lower end of the humerus as a result of the injury. Capitellum is in place and result as to appearance and function perfect.

region. X-ray showed it to be a fracture of the external condyle involving mainly the capitellum. Attempt at closed reduction failed. Operation five days after injury through a lateral incision. The fragment was found with fractured surface rotated outward. It was reduced with some difficulty and secured with sutures. The arm was put up in acute flexion maintained by a starch bandage. The boy was discharged from the hospital on the third day. At a follow-up examination six months later, it was noted that functional recovery was complete.

Case V.—Doctor Donovan. M. M., seven years old, fell about eight feet, striking his left elbow. (1926.) X-ray showed a laterally displaced fractured external condyle with fractured surface outward. Attempt at reduction was unsuccessful. Operation seven days after injury. Incision in the antecubital space along the medial border of the brachio-radialis. The radial nerve was identified and pulled inward. The fragment was replaced and the periosteum sutured. At the follow-up examination two months later there was a complete return of function.

It is not stated that all irreducible fractures of the external condyle fall into this group. It does seem to the writer, however, that the cases here presented are typical and the recognition of their characteristics important

because, contrary to the vast majority of fractures in children, the indication for early open operation is clear.

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FRACTURE OF THE FIFTH METATARSAL BONE*

WITH SPECIAL REFERENCE TO DELAYED UNION

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Twenty-one cases of fracture of the fifth metatarsal bone will be considered to illustrate a tendency toward delayed union probably caused by poor blood supply. Knowledge of this tendency is necessary for prognosis and treatment.

Fig. 1.—Shows the epiphysis of the tuberosity in an eleven-year-old boy.

History.—Much has been written concerning fractures of the metatarsals. The interest in their evolutionary history lies in the fact that even to-day such fractures frequently go unrecognized, especially if produced by indirect violence. Cumulative evidence seems to show that writers have been puzzled by the long disability frequently accompanying the comparatively slow healing of fractured metatarsals. The "fussgeschwulst" (foot-œdema) of the Germans was first described by Breithaupt [1] in 1855. He noted that soldiers on the march were frequently disabled by painful, swollen and tender feet, he attributed this condition to strained ligaments and tendons. In 1877, Wiesbach [2] named it "syndesmitis metatarsea" and in 1884, Laub [3] referred to it as the "periostitis of fatigue." Pauzat [4] in 1887 interpreted this condition as an "osteoplastic periostitis"; in 1888, Poulet [5] described it as a "rheumatic osteo-periostitis", and in 1891, it was named "Inflammation periosto-arthritique du Pied" by Martin.[6] Then followed discussions by Rittershausen [7] and by Busquet.[8] It was not, however, until 1897, that Schulte [9] first thought that this condition was a fracture, and in 1898, Kirchner [10] definitely proved this theory by röntgeno-

* Read before the Orthopædic Section of the New York Academy of Medicine, April 15, 1927.

gram. Subsequently there have been many articles on the "marching fracture" of the British and Americans, the "pied forcé" of the French, and the "fussgeschwulst" of the Germans. Only recently Murk Jansen [11] has called attention to this condition. He believes that a spasm and pull of the fibres of the interosseous muscles produce either a subperiosteal hemorrhage or a disturbance in circulation to cause the bone thickening seen in the röntgenogram. Meiser [12] found in his statistics that only one-third of fractured metatarsals showed distinct evidence of the lesion in the X-ray picture. He also states that the röntgenogram does not show the formation of callus often before the tenth day and frequently not until three weeks after fracture. Massacré [13] also stresses the usual delay in bone repair. Weichelt [14] thinks that perfect union rarely can be accomplished in fractured metatarsals, especially when produced by a twist. Graham [15] reports the case of a man of fifty who had a fracture of the base of the fifth metatarsal caused by indirect violence. The first examination, five weeks after the fracture had occurred, showed that no union had taken place. Young [16] had a case of fracture of the distal end of the fifth metatarsal in which non-union was verified by X-ray. Removal of the head of this bone did not relieve the metatarsalgia, but subsequent exsection of the head of the adjacent bone produced some relief. All the foregoing facts seem to indicate the validity of the contention that "fussgeschwulst" is most likely due to a fracture of one of the metatarsals. It will later be shown how delayed union in some fractures of the fifth metatarsal could probably explain the picture presented in "fussgeschwulst".

FIG. 2.—The same bone shown in Fig. 1, at fourteen years and three months, to demonstrate the advance in ossification.

Statistics.—It is of interest to note the relative frequency of fracture of the metatarsal bones. In 491 cases, Kirchner [17] found the fractures distributed as follows:

I	II	III	IV	V
0	253 (52%)	198 (40%)	32 (6%)	8 (2%)
	Distal Third 52%	Middle Third 42%		Proximal Third 6%

TABLE I.

*Synoptical Table of Twenty-one Cases of Fracture of the Fifth Metatarsal.**

No.	Age	Sex	Trauma Direct	Trauma Indirect	Site and type of fracture	Weight bearing	Length disability	Laboratory findings	Follow-up	Remarks
149173	25	F	+		Distal end of shaft, transverse, head displaced mesially	14 weeks	6 months	Urine—negative Wassermann—negative Blood calcium....10.04 } mgs. per Blood phosphorous 2.5 } 100 c.c.	Union in about 20 weeks, with some pain and swelling beneath malleolus. At 9½ months slight pain around ankle and swelling beneath malleoli on walking. Slight tenderness at site of fracture	False point motion at 12 weeks. Delayed union.
128576	40	F		+	Base—Transverse—no displacement	9 weeks	6 months	Urine—negative Wassermann—negative. Blood calcium.....9.45 } mgs. per Blood phosphorous 3.8 } 100 c c.	2½ years. Slight tenderness over site of fracture. Some residual decalcification of metatarsals	Rarefaction of metatarsals predominant in X-ray. Delayed union.
131625	31	M	?	?	Base—transverse, comminuted	6 weeks	11 weeks	Urine—negative Wassermann—negative Blood calcium.... 10.9 } mgs. per Blood phosphorous 3.3 } 100 c.c.	28 months—no symptoms or signs. By X-ray thickening of bone at site of fracture	Delayed union.
130169	34	M		+	Base, complete—no displacement	6 weeks	3 months			Probably delayed union.
120159	34	F	+		Base—no displacement	5 weeks	4 months			Probably delayed union.
117073	24	F		+	Distal end shaft—slight displacement proximal fragment	4 weeks	3 months		4 months—no symptoms or signs	
130590	26	F	?	?	Base—transverse, no displacement	5 weeks	3 months		6 months—no symptoms or signs	

142498	41	F	+		Distal end shaft, incomplete, transverse	4 weeks	3 months	Urine—negative Wassermann—negative Blood calcium 10.02 } mgs. per Blood phosphorous 2.54 } 100 c c.	16 months—no symptoms or signs. X-ray shows firm union	
149373	56	F		+	Tuberosity	8 weeks	3 months	Urine—negative Wassermann—negative Blood calcium.... 9.55 } mgs. per Blood phosphorous 2.9 } 100 c.c.	3 months—considerable œdema dorsum foot-tenderness at site of fracture. X-ray shows moderate amount callus	
118592	60	M		+	Base transverse, no displacement	6 weeks	2 months		13 weeks—no symptoms or signs	
143848	19	F		+	Tuberosity	4 weeks	1½ months	Urine—negative Wassermann—negative	1 year—no symptoms or signs	
113604	46	F		+	Base—incomplete	2 weeks	5 weeks		3 months—slight swelling about ankle on walking	
126070	47	M	+		Base, transverse, lateral displacement distal fragment	22 days	5 weeks			
111749	50	F		+	Base	4 days	4 weeks			
109343	35	M	+		Tuberosity	3 weeks	4 weeks			
17668	41	M		+	Shaft—comminuted, no displacement	2 weeks	2 weeks			
136100	41	M	+		Shaft—middle third, oblique		Did not return			
133746	55	F	+		Shaft—proximal third, oblique		Did not return			
121326	20	M		+	Base—no displacement		Did not return			
115829	19	F	+		Base—transverse		Did not return			
132158	13	M		+	Base, transverse epiphysis tuberosity present		Did not return			

*The predominating symptoms and signs in all the cases were pain, swelling, ecchymosis, and tenderness. They were immobilized either by a posterior moulded plaster splint for the foot and leg or by a plaster boot. The cases that were followed received physiotherapy at frequent intervals.

Summarizing 233 cases, Nion [18] found the fracture 115 times on the right side and 118 times on the left.

Anatomy.—The fifth, the most exposed of the metatarsal bones, is one of the smallest, yet one of the strongest of them all. It develops a separate osseous centre in the distal end between the third and the fifth years, and sometimes as late as the eighth year. Between the eighteenth and the twentieth years the epiphysis unites with the shaft. Kirchner [19] describes a separate epiphysis for the tuberosity, which Gruber [20] believes to be only occasional. On the other hand, Schouwey [21] found it constant and occurring in the thirteenth and fourteenth years. In one specimen that he examined microscopically he was able to demonstrate that the centre of ossification is first developed in the tendon of the peroneus brevis. Figure 1 shows the epiphysis of the tuberosity in a boy of eleven and Fig. 2 shows the advance in ossification in the same bone at fourteen years and three months. The base, tuberosity, shaft and head make up the entire bone. The tuberosity, rather prominent and nipple shaped, projects on the lateral aspect of the base, which, by a posterior facet, articulates with the cuboid, and, by a mesial facet, with the fourth metatarsal. The shaft differs from any of the other metatarsals in being compressed from above downward, instead of from side to side, so that it presents superior, inferior and mesial surfaces. The head is small, turned somewhat laterally, and has a pair of lateral tubercles at the end of the dorsal aspect of the shaft. The muscle and ligamentous attachments are shown in Fig. 3.

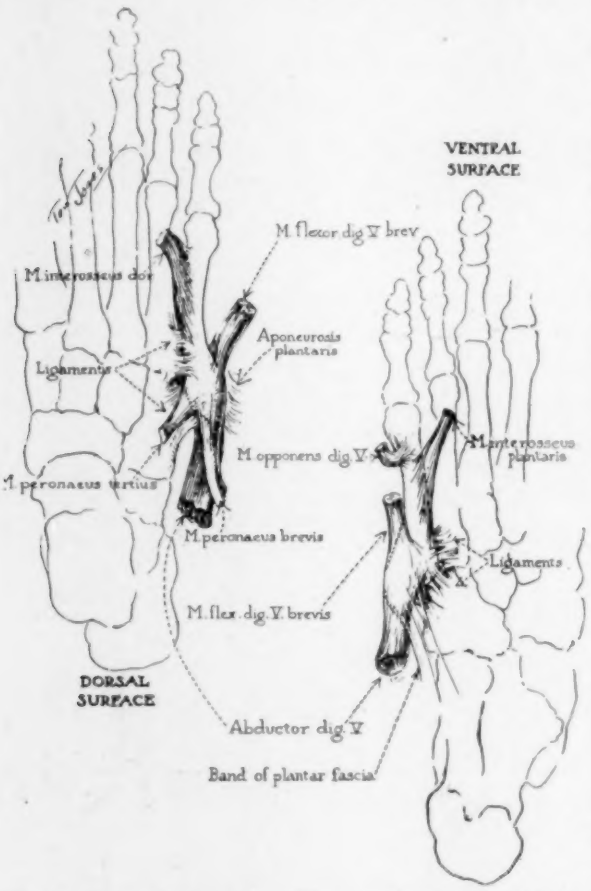

FIG. 3.—The muscle and ligamentous attachments to the fifth metatarsal. (From Christopher [22].)

Blood Supply.—Comparison shows that the rate of union in fractured

metacarpals is more rapid than that in metatarsals, and that the calibre of the blood-vessels supplying the former is larger than that of the blood-vessels supplying the latter. In addition, weight-bearing tends to compress the branches of the plantar arch. The nutrient vessel of the fifth metatarsal, which, according to Piersol,[22] may be absent, enters by a foramen usually situated on its tibial side, and it is significant that this vessel is as a rule directed toward the base. (Fig. 4.) It is represented only by a few fine branches which anastomose with the small blood-vessels of the epiphyses. The latter are more abundant than the former. Johnson,[23] in his work on the blood supply of the diaphysis, concludes that the factors essential in bone repair are, in the order of importance, the nutrient artery, and the vascular networks of the metaphysis and of the periosteum.

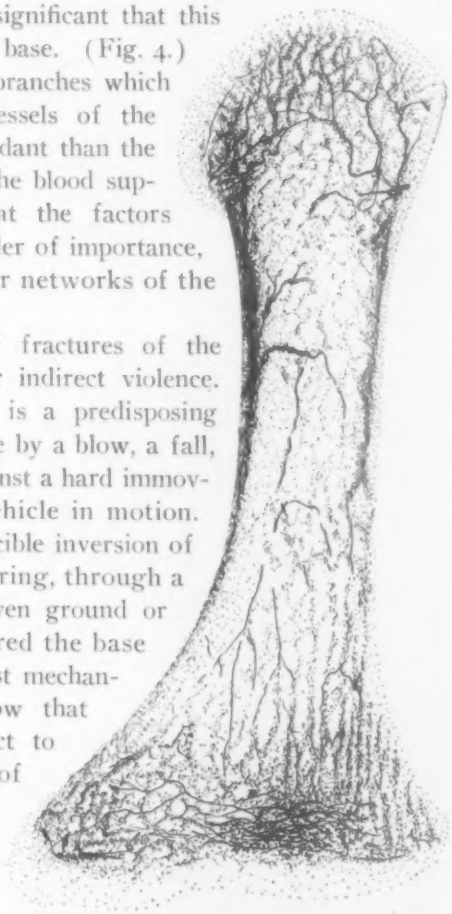

FIG. 4.—The blood supply of the fifth metatarsal. Note the fine primary nutrient vessel and the small blood-vessels of the epiphyses. (From Lexer [25].)

Mechanism.—The mechanism of fractures of the fifth metatarsal is through direct or indirect violence. The exposed position of this bone is a predisposing factor for its injury by direct violence by a blow, a fall, striking the outer side of the foot against a hard immovable object, and by a wheel of a vehicle in motion. The indirect violence is usually a forcible inversion of the foot accompanied by weight-bearing, through a fall, a jump, a sudden step on uneven ground or dancing. Sir Robert Jones [24] fractured the base of his own fifth metatarsal by the last mechanism. A glance at Fig. 5 will show that whereas the proximal end is subject to strain by plantar fascia and a pull of peroneus brevis and tertius, the distal end is acted upon by the dorsal and plantar interossei and the opponens digiti quinti.

An analysis of twenty-one cases given in table shows the following:

1. Sex: Males, 9 (47 per cent.). Females, 12 (53 per cent.). 2. Age: Youngest, 13 years. Oldest, 60 years. Average, 36 years.

		Base	Tuberosity	Shaft	Distal Extremity	Total
3. Violence	Direct	3 (38%)	1 (12%)	2 (25%)	2 (25%)	8
	Indirect	7 (64%)	2 (18%)	1 (9%)	1 (9%)	11
	Doubtful	2 (100%)				2

4. Predominant symptoms and signs—pain, swelling, ecchymosis and tenderness.

5. Length disability (16 cases): Shortest, two weeks. Longest, twenty-four weeks. Average, ten weeks. 6. Females tend to have a longer disability than males. 7. The end results are good.

A further analysis of the 20 cases in adults shows that there were five cases which from clinical and X-ray evidence had delayed union. This occurred four times at the base and once at the distal extremity of the shaft. All the other cases that could be followed had characteristic pain, tenderness

A B

FIG. 5.—Case No. 149,173. To show a fracture of the distal extremity of the shaft of the fifth metatarsal nine days after injury.

and œdema at and surrounding the area of fracture, which extended over periods of weeks or months. While it is true that soft part injury in association with the fracture might produce these symptoms for a short period, still interference with proper bony union is the most plausible explanation for the long disability.

One would expect in a long bone as small as the fifth metatarsal, that enough union would take place in the cancellous portion in about ten days to

prevent mobility of the fragments. In the cortical bone of the shaft, normal calcification should occur in about three weeks. When delayed union occurs, some attempt at repair is being made, but it is slow nevertheless. Estes [25] considers delayed union to have taken place when it becomes evident eight days or more after the upper limit. When union has taken place, abnormal mobility cannot be detected at the site of fracture. This, however, has no relation to the strength of repair. When there is abnormal mobility after six months, non-union is said to have occurred. The relative frequency of delayed union in all bones is variously given by different authors. Nutter [26] quotes Boyd and also Von Bruns, who estimate that it occurs in about 1¼ per cent. of fractured limbs. Hey Groves,[27] however, gives the frequency between four and five per cent. The usual causes for delayed union are, excluding compound and badly comminuted fractures:

FIG. 6.—The same as Fig. 5, after one month. Note the very slight callus on the mesial aspect of the fracture line.

1. Circulatory disturbance. 2. Infection. 3. Syphilis. 4. Low calcium and phosphorus content of the blood (Petersen).[28] It will be seen that all the factors except circulatory disturbance have been eliminated from the group of cases under consideration.

The type of bone repair in fractured metatarsals is rather interesting. Several varieties of callus may be formed.

1. It may be so small as to be scarcely visible in the X-ray. This is especially true when there has been no displacement of fragments.

2. It may be excessive and form the so-called "cal vicieux." This frequently occurs when the fracture has been overlooked and the patient walks about. It may be so large as to impinge on an adjacent metatarsal or cause pressure on the plantar nerves.

3. It may be long and thin, stretching almost the entire length of the shaft.

4. It may be delayed for a long time and then appear quickly or slowly.

It must be remembered, however, that the time for the appearance of callus in the X-ray is variable. Twenty-two days after fracture of a metatarsal, Kirchner [17] found a thick callus by röntgenogram which could not be easily detected on examination. Thiele [29] found no callus fifteen days after such a fracture, but fifteen days later it was marked. This bears out

A B

FIG. 7A.—The same as Fig. 5, after three months, when false point of motion could still be elicited. Note the slight amount of callus mesially and apparently none laterally. The bones of the foot are rarefied. B. Showing rarefaction of the bones of the foot.

the observation that there may be apparent inactivity in callus formation for several weeks and then calcification may occur quite rapidly.

Treatment.—On the basis of all the foregoing facts, the treatment recommended is as follows:

1. Immobilization of the foot and leg by means of a posterior moulded plaster splint. Crutches may be used.

2. Measures such as deep light therapy and gentle massage to promote hyperæmia. These methods are better with the foot in the splint.

FIG. 8.—The same as Fig. 5, after six months, showing union.

FIG. 9.—Follow-up röntgenogram of Fig. 5, after nine months showing firm union. Note the thin callus rounded off.

FIG. 10.—Case No. 131,625. To show a transverse, comminuted fracture of the base of the fifth metatarsal bone.

3. If there is a tendency to delayed union, the administration of calcium [30] or cod liver oil, heliotherapy, and perhaps scarification of the fractured ends with a needle introduced through the soft parts in order to produce bleeding. The last is recommended by Darrach [31] in some cases of non-union.

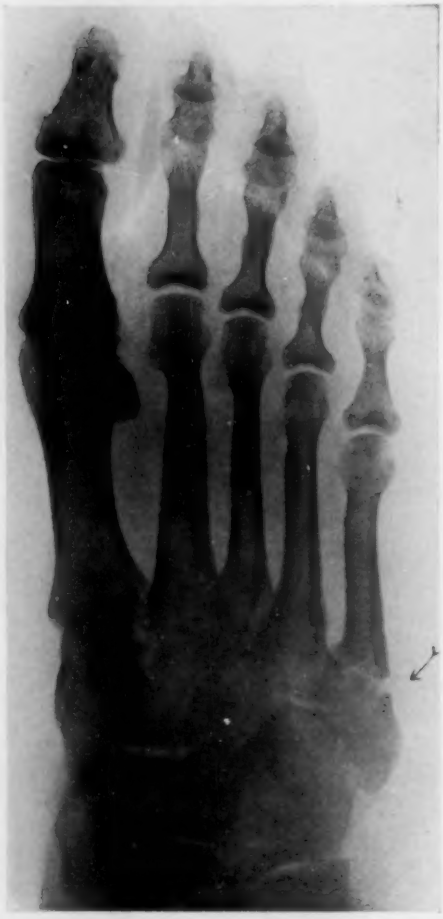

FIG. 11.—The same as Fig. 10, after one month. Note that there is only very slight callus formation.

FIG. 12.—The same as Fig. 10, after twenty-eight months, to show perfect union and considerable thickening of the bone at the site of fracture.

4. Avoidance of excessive trauma to demonstrate mobility of the fragments.

Prognosis.—This must be guarded as to the time and extent of disability. The best prognosis can be given for fracture of the tuberosity.

Summary.—Twenty-one cases of fracture of the fifth metatarsal are reported, with their analysis. Twenty were in adults, and of these five showed clinical and X-ray evidence of delayed union. All the latter had a normal blood calcium and phosphorus and a negative urine and blood Wassermann. All the other cases that could be followed had clinical symptoms over such long periods that it is fair to assume some interference in bone repair. The

main cause of this condition is probably the poor blood supply of this bone. The treatment is directed toward immediate immobilization and hyperæmia. The experience from all these cases tends to show that too long immobilization produces bone atrophy which certainly cannot help bone repair. Weight-bearing in a strong moulded plaster splint before one month, where possible, is suggested to overcome this bone atrophy. Between the eleventh and sixteenth years, the epiphysis of the tuberosity is not to be mistaken for fracture.

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